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EFFECTS OF SIMULATED SURFACE EFFECT SHIP MOTIONS ON CREW HABITABILITY—PHASE II

VOLUME 4
CREW COGNITIVE FUNCTIONS, PHYSIOLOGICAL STRESS, AND SLEEP

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

As part (PhaseII) of a continuing program for establishing habitability design criteria for a large-scale Surface Effect Ship (SES), 19 novice U.S. Naval enlisted personnel were exposed to motion for periods of up to 48 hours in a closed cabin mounted on a three-degree-of-freedom simulator (the ONR/HFR Motion Generator). These subjects were variously exposed to eight conditions of full-amplitude or attenuated SES motion, representative of fully developed starboard bow seas traversed at high speeds (i.e., Sea State 3 at 80 kt, Sea State 4 at 60 kt, and Sea State 5 at 40 kt). The results described here were obtained from 16 of these subjects, who were exposed to one or more motion conditions, and who provided comparable data during confinement in a similar, but static, cabin environment. The results pertain to the subjects' (1) cognitive or visual functions, (2) physiological stress, and (3) sleep. Other aspects of their reactions to motion are described in companion volumes of this series.

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motion on crew health and performance. Other organizations preparing the companion volumes are Naval Sea Systems Command (PMS-304), Systems Technology, Inc., and Naval Aerospace Medical Research Laboratory Detachment. NOTE: This volume was published and distributed separately by Human Factors Research, Inc., in May 1976 under the title "Simulated Rough Water Operation During Long Cruises in a 2000-Ton Surface Effect Ship--Phase II. Volume 4: Crew Cognitive Functions, Physiological Stress, and Sleep," TR 1757-2.

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INTRODUCTION

The role of Human Factors Research, Incorporated (HFR), in the Phase II investigation of the effects of simulated surface effect ship (SES) motions on crew habitability can be broadly catagorized as follows:

1. To assist the Surface Effect Ship Project Office (PMS 304) in experimental design, developing test protocols and test scheduling.

2. To provide engineering, logistic, housekeeping, and data acquisition support for all simulator operations, including the collection of all performance data.

3. To assess motion effects upon certain psychological and physiological functions in the test crewmen (subjects) during exposure to motion.

HFR's efforts to meet the first and second responsibilities are described in Volume 2 (Facilities, Test Conditions, and Schedule) of this series. The research effort mounted to meet the third responsibility, and the results obtained are described in the present volume. Basically, the objectives of that effort were as follows:

1. To determine whether simulated SES motions affect subject capabilities to perform operational-like tasks wherein performance depends heavily upon higher-order cognitive processes such as attention, perception, and memory but not primarily upon motor coordination and control.

2. To assess the subjects' experience of whole-body stress during motion exposures from the measurement of biochemical stress correlates.

3. To determine the quality and quantity of sleep obtained by subjects during motion exposure from electroencephalographic (EEG) recordings and subjective evaluation.

The first objective was approached by designing and administering a battery of simulated operational tasks comprising two types of radar monitoring, cryptographic decoding and encoding, and navigational information processing and plotting. One radar task, *missile detection*, was structured to test the crewman's ability to maintain attention and discriminate occasional targets from random noise, on the basis of relative brightness, under conditions of monotony and low information rate (stimulus underload). The other radar task, *collision avoidance*, tested the ability to maintain attention and discriminate threatening from benign contacts, on the basis of complex temporal and spatial patterns of radar imagery presented at a high information rate (stimulus overload). The cryptographic tasks were designed to measure near-range visual search and character recognition and motivation to perform tedious work. The navigational task required the acquisition of aural information regarding reported radar contacts, the translation of that information into a ship-centered spatial coordinate system, and perceptual-motor coordination for plotting the reported contacts.

Assessment of each subject's experience of stress was accomplished in a conventional manner by assaying urine samples to determine the excretion rates of catecholamine hormones, adrenaline. and noradrenaline.

The analysis of the quantity and quality of sleep was accomplished in two ways. First, electroencephalogram (EEG) recordings were taken from subjects and, later, selected records were scored visually using standard techniques. Second, the subjects' self assessments of degrees of alertness/sleepiness were elicited at regular intervals during all experimental and control conditions. Oral temperatures were recorded from the subjects at these times, and trends in oral temperatures were examined to determine whether circadian cycles of whole-body metabolism were affected by changes in sleep patterns, in correspondence with the self assessments.

GENERAL METHOD

Subject Training

Each of the subjects was individually briefed, then trained by one of the Test Administrators on 3 consecutive days, prior to the commencement of static or motion runs. The overall training schedule is given in Volume 2 of this series. On the first day, each subject received a 2-hour briefing regarding the nature and purpose of every task in the test battery. On the second and third days, he received a total of approximately 16 hours of intensive training on all tasks. The nature of that training with respect to tasks described in this volume is described below.

Radar 1 (missile detection). On the second training day the subject was familiarized with the task in the settings where it was later performed under experimental conditions (15 minutes). He then undertook three successive 15-minute tests at the task wherein performance feedback was either given on a response-by-response basis (first test), or upon completion of the test (second and third tests). On the second training day he performed the task essentially as he would later under experimental conditions, without feedback. His performance was evaluated to determine if he was behaving in a stable manner, by detecting at least 80% of the targets in less than 7 sweeps with less than 10 false detects. Every subject performed within these criteria on the second day.

Radar 2 (collision avoidance). Training for the *collision avoidance* radar task was essentially the same as for the *missile detection* task, as described above.

Cryptographic coding and decoding. On the second day, the subjects were individually introduced to the task, and then each subject performed separate coding and decoding tests at their own pace. These tests were scored with the subject present and the cause of every error was determined and discussed to prevent its reoccurrence. Finally, on the third day, each subject again performed one timed test at each cryptographic task. If he performed without error and within 15 minutes, training was concluded. Otherwise, he repeated the test until he met that criterion. No subject ever required more than one replication before satisfying the criterion.

Navigational plotting. The greatest attention was given to training the subjects on this task because it was expected to be the most difficult. On the second training day, each subject was given 15 minutes of basic instruction on reading nautical maps, converting radar coordinates into ship-centered polar coordinates on the map, and using a drafting arm attached to a plotting board. Next he was guided through a 15-minute test by a highly experienced Test Administrator. Finally, he performed a similar test on his own. That is, feedback was withheld until the end of the test when his plotting record was scored and his errors were discussed. On the third day, the subject undertook an unaided, 30-minute test, exactly as he would later under experimental conditions. The test was discontinued, and later repeated, if the subject felt that he had become totally disoriented. Otherwise, his plotting record was scored and he was judged to have performed adequately if he satisfied the following criteria: (1) plotted his ownship's course within ±10° of the true course, (2) plotted every reported radar contact in the time allowed, and (3) plotted the position of all reported radar contacts within ±10% of their indicated position. Several subjects failed to satisfy one or more of these criteria and were required to repeat a similar plotting test at a later date, scheduled at the convenience of the subject and Test Administrator but before the former performed the task under experimental conditions.[1]

[1]There was one exception to this. A subject who appeared to be performing the task in a competent manner later became an alternate subject; he became a regular subject when his predecessor chose to drop out of the experiments due to motion sickness. When the subject first undertook the task in an experimental condition, he failed utterly, and no further plotting trials were administered to him in that condition. He was subsequently retrained during a break in the scheduled experiments and later performed in an acceptable manner.

TEST SCHEDULE

Long (>24-Hour) Missions

The nominal start and finish times for trials at each of the tests described in this volume are given in Table 1. In general, tests began and finished within 5 minutes of the scheduled times. Exceptions to this occurred as the result of equipment failures. However, delays of more than about an hour occasioned cancellation of the particular test, rather than a further disruption of the schedule.

TABLE 1

SCHEDULE OF TESTS IN LONG MISSIONS
ACCORDING TO CLOCK TIME

Test	Work/Rest Schedule	
	Night-Sleepers	Day-Sleepers
Visual acuity	1215 - 1230	0015 - 0030
Radar 1	1230 - 1500	0030 - 0300
Crypto-decode	1600 - 1615	0400 - 0415
Navigation	1615 - 1700	0415 - 0500
Crypto-encode	1700 - 1715	0500 - 0515
Radar 2	1715 - 1930	0515 - 0730
Visual acuity	1945 - 2000	0745 - 0800

Short (6-Hour) Missions

Short missions began at either 0700 hours or at 1400 hours, continuing in both cases for the next 6 hours. Visual acuity trials were administered within the first and final hours. A single trial at the navigation task was administered to one of the two subjects within each cabin during the second hour, while the other subjects performed both cryptographic tasks. Those assignments were reversed in the third hour with the former subjects performing the cryptographic tasks and the latter, the navigation task.

DEFINITION OF EXPERIMENTAL CONDITIONS AND INDIVIDUAL SUBJECT EXPOSURES AS RELEVANT TO DATA ANALYSIS AND INTERPRETATION

Data Collection Problems

It is not the purpose of this volume to describe the experimental design as originally conceived, or to detail the circumstances which led to repeated modifications of that design in actual practice. This is done in Volume 2. However, the frequent planned and unplanned modifications of the design forced an unexpectedly ad hoc approach to data analysis and interpretation. The actual experimental conditions were in some cases quite different from those originally envisioned, principally as the result of equipment malfunction and the unexpectedly high incidence of motion sickness among subjects in the more severe motion environments. Motion sickness was generally incapacitating to the subjects, rendering most incapable of performing all but the simplest experimental tasks. Moreover, sick subjects tended to exercise their prerogative of leaving the test environment, in some cases long before the scheduled completion of their motion exposure.

The net result of these problems was a fragmentary and recognizably biased data base, which deviated from that expected in the following respects:

1. More variations of the three standard motion conditions (i.e., 80 kt, SS3; 60 kt, SS4; and 40 kt, SS5) were used, with fewer subjects in each condition.

2. Nearly all performance data were collected from subjects not then experiencing symptoms of motion sickness. Most sick subjects could not, or would not, perform most experimental tasks and usually left the test environment after a variable period of incapacitation.

3. Initially, only the Long Missions (i.e., >24 hours) were planned. When it became apparent

that few subjects would tolerate severe motion exposures for periods of that duration, the Short Missions (6 hours) were scheduled.

4. It eventually became apparent that a relatively large proportion of the subjects were unable or unwilling to tolerate motion in the more severe conditions, due to motion sickness. In view of this, the decision was made to use only those subjects in the more severe conditions, who had previously demonstrated an ability to tolerate an extended exposure to motion in the less severe condition. It was hoped that this revision of the original design would allow the most efficient use of the subjects to provide maximum data collection in the limited time available for testing. Yet it was recognized that the subject sample would be generally more biased, with respect to increasing resistance toward motion sickness, as the conditions increased in severity. That is, the group's resistance to motion sickness would increase, by subject pre-selection, from all variations of the 80 kt, SS3 condition to all variations of the 60 kt, SS4 condition and, further, to all variations of the 40 kt, SS5 condition.

5. Periods of data collection from subjects in the static cabin were originally scheduled in parallel with data collection from the moving cabin, with subjects alternating between environments. Due to the disruption of data collection in the moving environment, the schedule for data collection in the static environment was also modified so that static exposures varied in both number and duration for different subjects. The static exposures were designed to show baseline performance levels for subjects and control for the effects of confinement and time-dependent factors such as learning and boredom. This objective was only partially achieved as the subjects' baseline performance measures were obtained over different static exposure periods.

Approach to Data Analysis

Before the data were reduced, it was necessary to redefine the conditions of motion with respect to waveform and level of intensity. There were, as mentioned earlier, three basic input waveforms. For planned and unplanned reasons (see

Volume 2), each of these were delivered either at full-heave amplitude, or at various attenuated amplitudes in different motion conditions. (Roll and pitch motions were always delivered at full amplitude for a given condition, but always at relatively low levels with respect to heave motion.) For categorizing the actual conditions of motion in a manner permitting rational data reduction and analysis, overall heave output acceleration (rms g) was measured for every condition. Output heave acceleration levels at 90% or greater of full input levels were categorized as *full* amplitude; output levels of between 70% and 90% were categorized as *medium* amplitude; and output levels of less than 70% were categorized as *low* amplitude. The resulting categorization of all motion conditions is given in Table 2. Also shown in the table are the subjects who ran in each condition; their classification as day- or night-sleepers; their respective exposure periods; their waking and sleeping schedules; periods in which they were suffering from motion sickness to an extent which was evident from vomiting, or reported severe nausea; and the reason for terminating their particular exposures.

As shown in Table 2, motion sickness was experienced by some subjects in all but the least severe conditions (Low, 80 kt, SS3). Some subjects quit, often after a period of incapacitation, due to motion sickness in every other condition. These individuals provided little useful performance data, so any results provided by the remaining subjects must be considered as a sample of the capabilities of individuals not afflicted by severe motion sickness.

The least equivocal data were obtained in the Full, 80 kt, SS3 condition. None of the subject had been preselected as showing any partiuclar tolerance for motion. Of the 8 subjects who originally began a run, 7 were exposed for 24 to 48 hours. One became sick upon awakening from sleep, attempted none of the tasks described in this volume, and quit after

TABLE 2

SUMMARY OF CONDITIONS (INPUT WAVEFORMS AND NOMINAL LEVELS), OVERALL ACCELERATIONS, SUBJECTS, EXPOSURE TIMES, AND REASONS FOR TERMINATION

CONDITIONS				SUBJECTS[1]		
INPUT WAVEFORM	NOMINAL LEVEL	RUN NO.	OVERALL ACCELERATION (rms g)	DAY SLEEP	NIGHT SLEEP	REASON FOR[3] TERMINATION
80 Kt, SS3	Low	483	.127	43	50	S S
		485	.127	39	48	S S
80 Kt, SS3	Medium	424	.155	44	49	E E
		439	.149	47	52	S M
		440	.149	44 38	49	S M S
		455	.168	38	46	M M
		457	.168	35	49	S S
80 Kt, SS3	Full	487	.193	50	43	E E
		489	.193	48 51	39	S M S
		525	.193	60	40	S S
		527	.193	56	61	S S

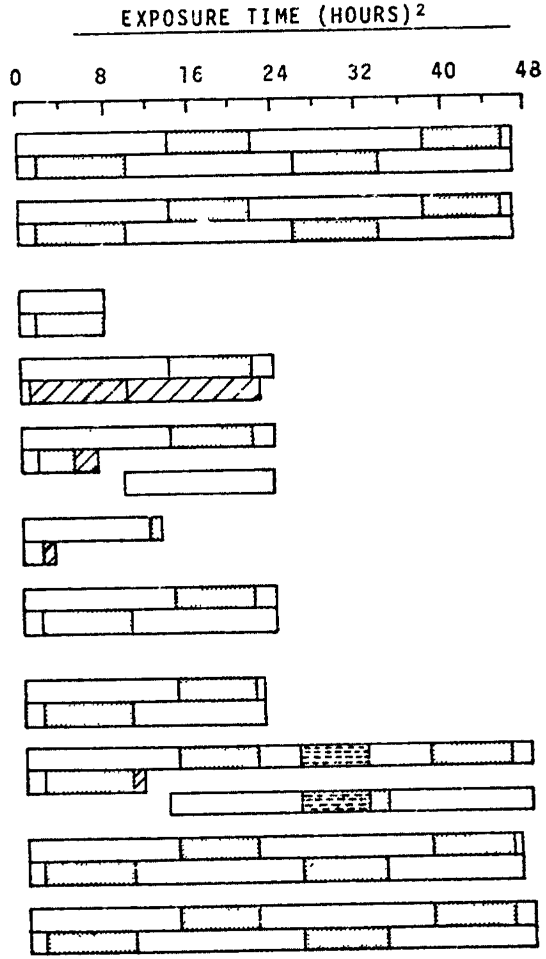


Table 2 (Cont'd, page 2)

CONDITIONS: INPUT WAVEFORM	CONDITIONS: NOMINAL LEVEL	RUN NO.	OVERALL ACCELERATION (rms g)	SUBJECTS: DAY SLEEP	SUBJECTS: NIGHT SLEEP	REASON FOR TERMINATION
60 Kt, SS4	Low	453	.170	38	46	S S
		454	.170	47	49	S M
60 Kt, SS4	Medium	529	.192		43 59	S S
		530	.192	40 51		S S
		532	.192		56 60	S S
		533	.192	61 57		M M
60 Kt, SS4	Full	446	.221	47	52	M E
		451	.221	47	49	M M
		550	.248	60	40	M M
		540	.248		43 60	S S
		541	.248	40 51		S S
40 Kt, SS5	Medium	535	.191		43 59	S M
		536	.191	40 51		S S
		538	.191	56 60		M S

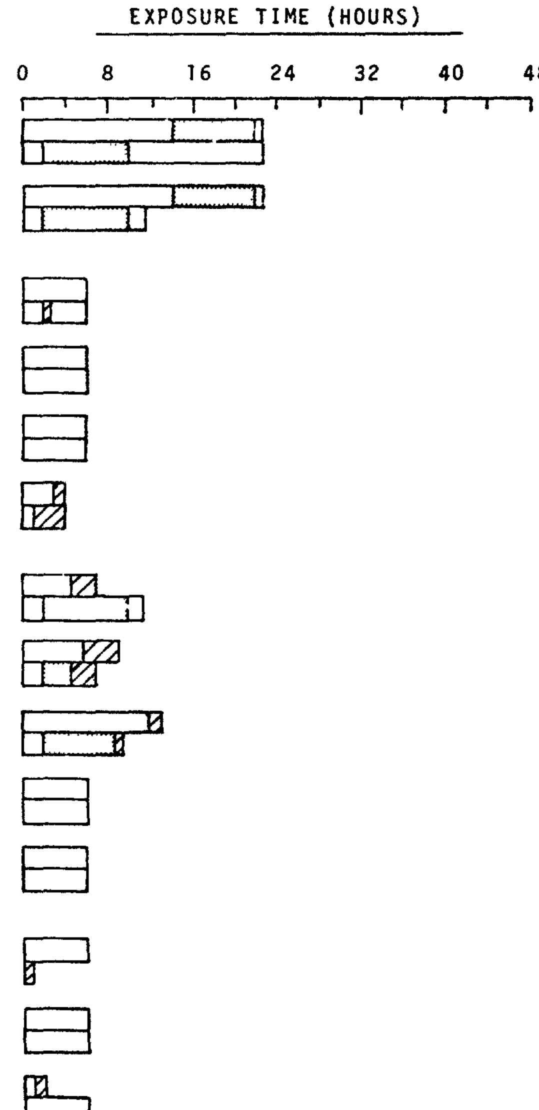
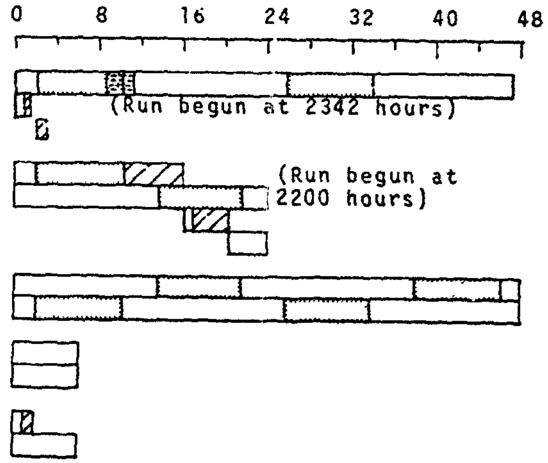


Table 2 (Cont'd, page 3)

CONDITIONS: INPUT WAVEFORM	CONDITIONS: NOMINAL LEVEL	RUN NO.	OVERALL ACCELERATION (rms g)	SUBJECTS: DAY SLEEP	SUBJECTS: NIGHT SLEEP	REASON FOR TERMINATION
40 Kt, SS5	Full	494	.254		43	S
				50		M
				48		M
		496	.254		39	M
				51		E
					58	M
					43	E
		547	.287		51	S
				43		S
		543	.287		43	S
					60	S
		545	.287	40		M
				51		S

EXPOSURE TIME (HOURS)



[1]Subject numerically coded by Naval Aeromedical Research Laboratory Detachment (NAMRLD).

[2]Exposure time identified with respect to scheduled activity and subject condition: open space--waking period and subject apparently normal; shaded space--sleeping period and subject apparently normal; crosshatched space--subject sick or severely nauseated; dashed lines--temporary machine breakdown.

[3]Reasons for termination: S--scheduled termination; E--equipment failure; M--subject aborts due to motion sickness.

about 12 hours of exposure. He was replaced by another subject who completed the scheduled 48-hour mission, experiencing approximately a 35-hour exposure. The data obtained from the 8 subjects who completed at least one 24-hour exposure to Full, 80 kt, SS3 motion may be regarded as the most complete and unbiased for determining some effects of a type of simulated SES motion. For that reason inferential statistical analyses were applied principally to those data. For the remaining conditions the results of performance testing were mainly treated in a descriptive manner. On the other hand, biochemical data were obtained from practically every subject, well or sick, in every condition. These were analyzed more extensively although the results obtained have to be interpreted in light of the preselecting bias noted above.

COGNITIVE TASKS

Radar 1: Missile Detection

Rationale and approach. The missile detection task was designed by O'Hanlon, Royal, and Beatty (1975) for measuring human ability to maintain attention in a simulated sea-surveillance radar watch, wherein critical contact frequency is relatively low and monotony is an intrinsic factor limiting performance effectiveness.

The task scenario was deliberately selected to represent one of the most critical and arduous operational problems that might be encountered by shipboard radar operators in times of war, viz., the detection of incoming surface-to-surface missiles, closing at high speed. For example, a missile 50 to 100 feet over the water would not provide radar returns until it was within 10 to 20 miles of the ship. With a closing speed in excess of 600 knots, this would allow less than 120 seconds between the earliest possible detection and final impact for missile interception. Any impairment in the radar operator's detection efficiency would seriously jeopardize the ship's survival. Exposure to SES motions might cause the loss of the operator's ability to sustain attention or interfere with his vision, or both. This task was employed to show whether such interference occurs.

The approach involved presenting simulated radar imagery on separate CRT (9-inch diameter) displays to subjects seated in both the static and moving cabins. The imagery was presented in standard ship-centered, Planned Position Indicator (PPI) format, consisting of a rotating (12 RPM) sweep line, painting continuous video noise and an occasional missile contact on the P7 CRT phosphor. Contact dimensions were 3 mm by 3°, with a brightness of 4.5 db, relative to the rms noise level.[2]

[2] Contact parameters were selected on the basis of a previous pilot study to yield detection latencies of three to four sweeps from alert subjects under optimal conditions.

Contacts were separately presented at randomly selected bearings, and initially at the periphery (full range) of the display, representing a distance of 20 NM. Successive contact repaints showed the missile moving along a constant bearing toward the center of the display at a simulated speed of 1200 knots. Contacts were on the display for a maximum of 1 minute (12 successive sweeps). As soon as the subject detected the contact, he pushed a DETECT button and verbally indicated the contact's bearing. His response was scored by the elapsed number of successive contact repaintings before detection occurred, or as the maximum number of successive repaintings (i.e., 12) if he made no response within the allotted time.

Apparatus. The subjects' displays were Wavetek (Mod. No. 1901-B) oscilloscopes, modified to have equal scan rates in both horizontal and vertical axes. These were adjusted initially, and maintained subsequently, to provide equal display luminance for a given signal input. The two displays were driven in parallel by the ONR/HFR General Purpose Radar Simulator under computer control (REDCOR RC-70). The computer was programmed to initiate and terminate the task, and to provide the system with contact timing and position information.

The subjects worked independently at the task in the two cabins. Their respective detection responses were registered in the computer from microswitch closures, achieved by depressing the corresponding DETECT buttons. The times of contact presentations and subsequent detection responses by each subject were immediately shown to the Test Administrator on the computer's teletype terminal. The subjects' respective verbal identifications of contact bearings were also transmitted via the intercom system to the Test Administrator who used the information to verify each subject's response with the teletype keyboard. Verified detection responses were scored by the computer, as were failures to respond. Unverified responses were scored as false detections.

A picture of a subject performing the task is given in Figure 1, and another of the appearance of the display during the presentation of a missile contact is given in Figure 2.

Procedure. Each subject was scheduled to perform the task once during each 24-hour period in the longer runs (see page 5 for daily schedule of tests). Each test was divided into three parts: a *Pretest* (10 minutes), a *Long Watch* (2 hours), and a *Posttest* (10 minutes). During the *Pretest* and the *Posttest* six contacts were presented. In the *Long Watch* six contacts were presented in each consecutive 20-minute period. Contacts were spaced closely in time during the two former tests but never closer than a minute apart. During the latter test the interval between successive targets varied randomly between 1 and 5 minutes.

Results and discussion. Every subject's average performance levels (i.e., sweeps-to-detect) were scored for the *Pretest*, *Long Watch*, and *Posttest* portions of the Radar 1 task. Individual scores for the static condition are shown in Appendix A, by subjects, repeated runs (where these occurred), and tests (days) within the same runs.

Eight subjects completed two or more runs (24 to 48 hours) in the static condition. Seven others completed only one run. This posed a problem for defining a static baseline level of performance, common to all subjects. Eventually, it was decided to use only the results from the first static run in subsequent static/motion comparisons. The decision seemed defensible for the following reasons. Results from the first static run should be comparable across all subjects. For those subjects who completed more than one static run, the level of performance in the first run was generally similar, or even superior, to later static performance levels, i.e., there was no evidence of general improvement due to learning. Because the first run performance scores seem to better represent the subjects' maximum performance capabilities in

Figure 1. Simulation of the Radar 1 *(missile detection)* task, showing the subject facing the CRT display. (In actual fact, the task was performed in semidarkness, wherein ambient illumination was provided from a single red, 15-watt, darkroom bulb.)

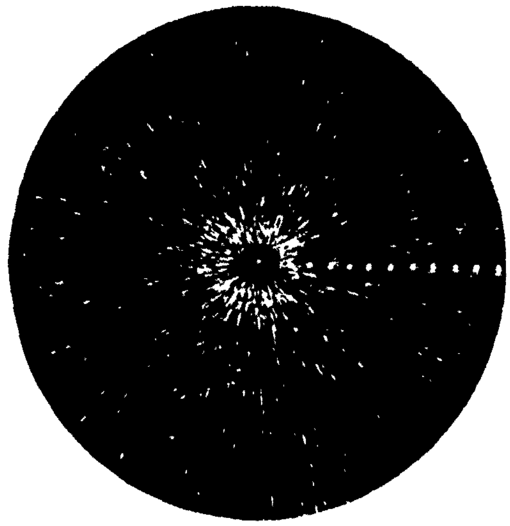


Figure 2. Time-exposure (120 seconds) photograph of simulated radar imagery during a "missile attack" in the Radar 1 *(missile detection)* task. (The target contact is shown traversing the display radius on a 90° bearing course, beginning at full range and ending at the blanked center position, in successive repaintings. Target intensity is exaggerated for photographic clarity.)

the static condition than later scores, the use of the former in static/motion comparisons should provide a more conservative test for adverse motion effects.

Average performance levels in the various motion conditions were calculated as in the static condition and are shown by conditions and tests within conditions in Appendix B. With one exception, no subject reported experiencing symptoms of motion sickness at the times of test administration. The exception was Subject 47 in Medium, 80 kt, SS3. He vomited before, during, and after the Radar 1 task but performed better *(Pretest)* or almost as well *(Long Watch)* as he did in the static condition. Nearly all of the other subjects who became sick withdrew before their first scheduled test. However, one subject (No. 40 in Full, 60 kt, SS4) reported his earliest symptoms after the first test, then vomited, and withdrew before the second test.

The differences between each subject's motion and static performance levels were calculated for the *Pretest*, *Long Watch*, and *Posttest*, separately. This was done for all motion conditions in which those tasks were administered in either one test, or in two tests on successive days. In all cases, the difference scores were obtained by subtracting that subject's average motion score from his corresponding static score (first or second test, respectively, during his initial static run). The results are shown in Figures 3, 4, and 5 for the

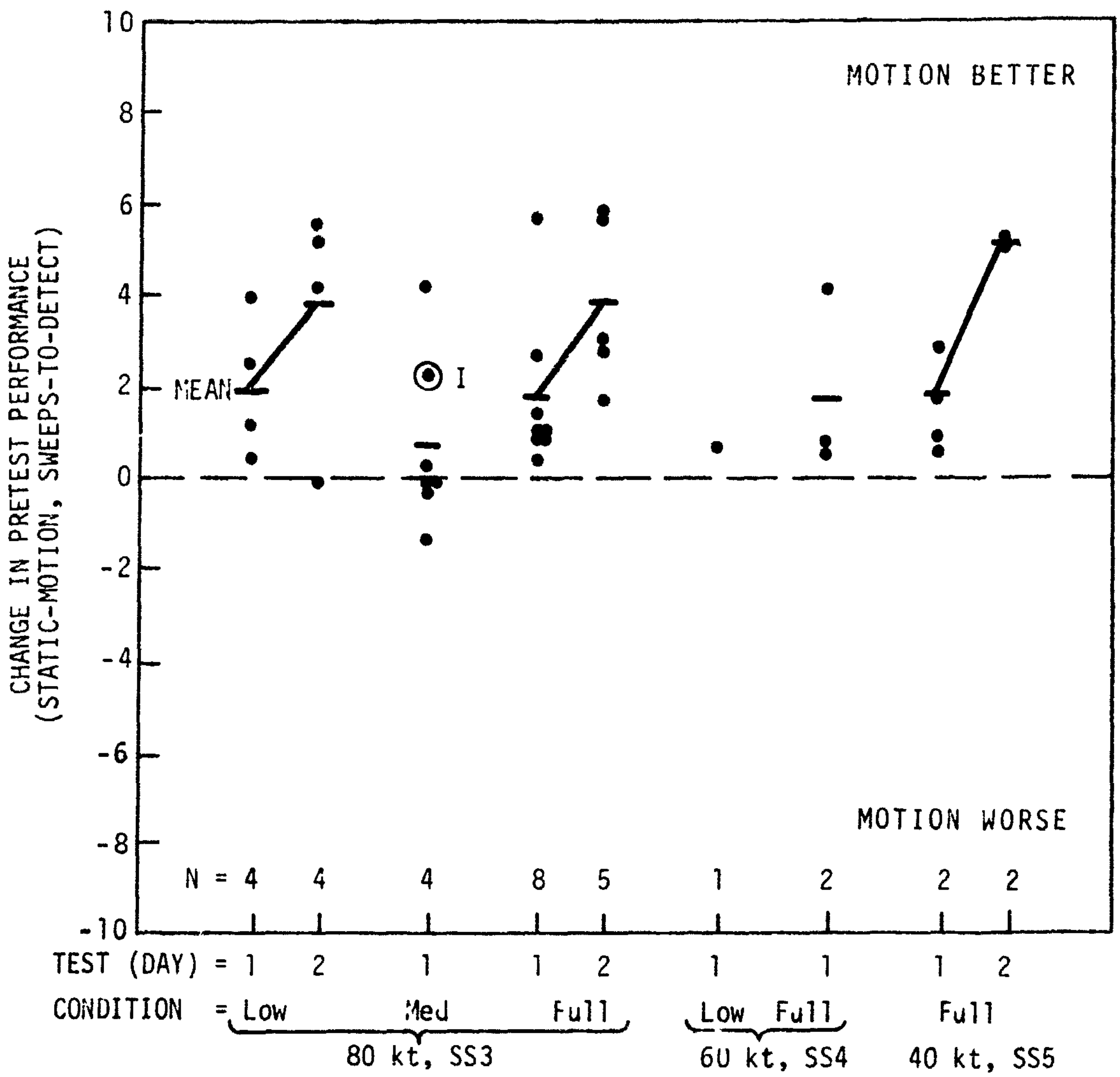


Figure 3. Change in average pretest performance from static to motion conditions on first and second days of exposure for all possible individual comparisons. (Horizontal bars indicate mean changes. Letter "I" indicates subject was sick at time of test in motion condition.)

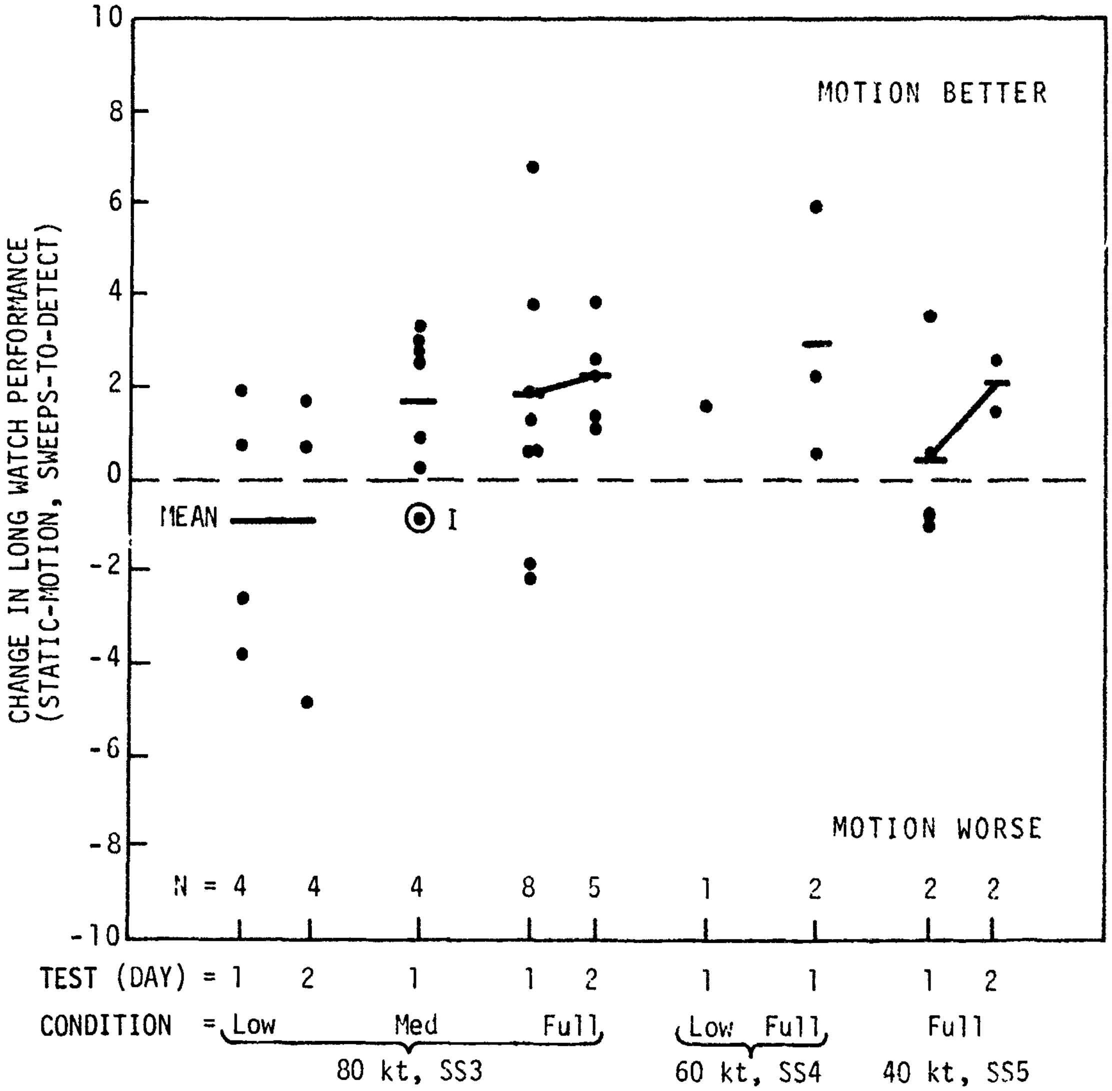


Figure 4. Change in average long watch performance from static to motion conditions on first and second days of exposure for all possible individual comparisons. (Horizontal bars indicate mean changes. Letter "I" indicates subject was sick at time of test in motion condition.)

Pretest, *Long Watch*, and *Posttest*, respectively. The *N* values shown at the bottom of each figure indicate the number of different individuals providing the data points shown above. In some cases the value of *N* was less than the number of data points shown for combination trials and conditions because some subjects' performance was measured under the same circumstances on more than one occasion. For example, Subject 49

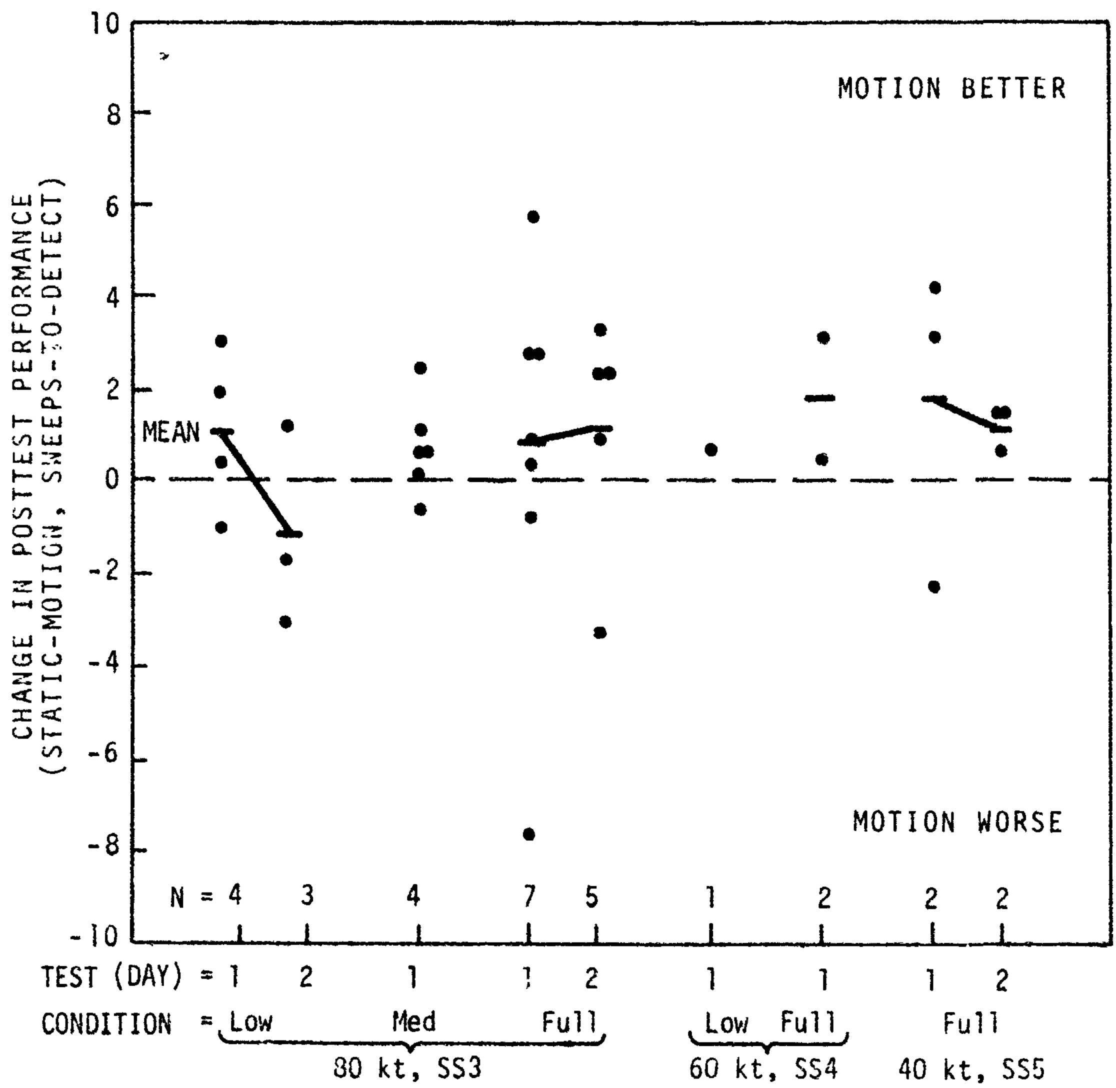


Figure 5. Change in average posttest performance from static to motion conditions on first and second days of exposure for all possible individual comparisons. (Horizontal bars indicate mean changes.)

was exposed to the Medium, 80 kt, SS3 condition on three separate occasions. There were three other subjects who experienced the same condition once, so the seven data points shown for that condition were obtained from four subjects (i.e., N = 4).

Collectively, the three figures show no general adverse effect of motion upon target detection performance in any part of the Radar 1 task. If anything, the performance of the subjects was generally better in all of the motion conditions than in the initial static condition. Better performance under motion conditions was probably attributable to greater motivation to perform the tedious Radar 1 task in the more challenging environment. Although the importance of the static results was emphasized to the subjects, several of them freely stated that they felt as though performance under motion was more important. Unavoidably, the subjects received more attention during and immediately following motion runs.

The small sample sizes in most of the motion conditions precluded inferential statistical tests for motion effects. However, it seemed meaningful to test the differences between static performance levels and performance levels measured in the Full, 80 kt, SS3 condition. Eight subjects began that condition, and although one dropped out due to motion sickness prior to his first Radar 1 test, he was replaced by an alternate subject who completed the original subject's test schedule. Therefore, eight subjects completed a 24-hour exposure during which each experienced one test at the Radar 1 task. Five of these subjects also completed a second test during their subsequent day of exposure. The rest did not, due to equipment failure that either stopped the run or prevented task administration. The analysis of motion effects in the Full, 80 kt, SS3 condition was performed on comparisons of the subjects' average static and motion performance levels, in both tests, for *Pretest*, *Long Watch*, and *Posttest*. The results are summarized in Table 3. In the *Pretest*, the subjects' performance was significantly better in the motion condition for both tests. Neither *Long Watch* nor *Posttest* performance levels differed significantly between conditions.

Even though these results fail to show any adverse effect of motion upon radar monitoring performance, no general conclusion

TABLE 3

SUMMARY OF *T*-TEST (CORRELATED MEANS) COMPARISONS OF AVERAGE PERFORMANCE LEVELS (SWEEPS-TO-DETECT) UNDER STATIC AND FULL, 80 KT, SS3 CONDITIONS FOR THE RADAR 1 (MISSILE DETECTION) TASK

TEST	TRIAL (DAY)	N	MEAN STATIC	MEAN MOTION	t	df	p
Pretest	1	8	4.95	3.09	-3.05	7	<.02
	2	5	6.44	2.50	-4.63	4	<.01
Long Watch	1	8	5.60	4.23	-1.33	7	NS
	2	5	6.34	4.00	-2.34	4	NS
Posttest	1	7	5.14	4.23	- .52	7	NS
	2	5	5.40	4.20	- .99	4	NS

seemed warranted. With the exception noted above, all results were obtained from subjects who were not at the time suffering from motion sickness. Moreover, the selective exclusion of susceptible subjects from the more severe motion conditions yielded a biased subject sample and, consequently, biased results. This may not be a critical limitation in every sense. Biasing was accomplished with respect to motion sickness alone. The effects of other hypothetically adverse factors, such as physical fatigue, should have been apparent from the results, if those effects were severe and independent of motion sickness. There is no way to determine from these results how sick individuals might have performed, if they were compelled to attempt the task. The performance of individuals who were not sick seemed generally unimpaired by the motion, at least in the Full, 80 kt, SS3 condition. From this, it seems that motion sickness is the limiting factor in determining how men can be expected to perform monitoring tasks (and probably most other tasks) during 24- to 48-hour exposures to similar motion environments.

Radar 2: Collision Avoidance

Rationale and approach. The collision avoidance radar task was originally developed by Schmidtke (1965) and substantially modified to meet the requirements of this study. Its purpose is to measure human attention and the ability to make complex perceptual discriminations in a simulated sea-surveillance radar watch, wherein the objective is to detect impending ship/ship collisons in a heavily congested area. In this task, information overload is an intrinsic factor limiting performance effectiveness.

The approach was similar to that used for the Radar 1 task. Subjects viewed the radar imagery in the same manner. However, the display was that of a ±60° forward sector scan, with the center shifted to the bottom of the display. The sector was traversed by the sweep line for 1.67 seconds, every 5 seconds. On each traversal, the sweep line painted 18 to 25 contacts without video noise. The position of each contact was varied on consecutive sweeps to simulate another ship's relative movement. The movement of each contact on the display was the analog vector sum of the other ship's course and speed, and the subject's own-ship's course and speed. With the exception described below, the contact generally progressed in a constant linear manner on the display as if the other ship were proceeding on a straight course, at a constant speed, while the subject's own ship was doing likewise. The other ships simulated speeds were between 15 and 30 knots, whereas own-ship's speed depended upon the experimental condition (i.e., either 40, 60, or 80 knots). Two types of contacts were presented. Most were benign, moving on parallel or divergent (>10°) courses from the indicated position of own ship; some were threatening, moving on a constant-bearing, closing-range course. Benign contacts could become threatening at any time as the consequence of a change in course. Other threatening contacts appeared first at the display periphery and remained on a collision course throughout their traverse of the display.

The subject's task was to continuously monitor the display, discriminating between threatening and benign contacts, responding whenever threatening contacts were sighted by pressing the DETECT button, and verbally indicating the contact's approximate range and bearing. His verified responses were scored as the percentage of the collision course remaining to be traversed before collision would occur.

Apparatus. The apparatus used in the Radar 2 task was the same as that in Radar 1. A picture of the appearance of the display during the presentation of a threatening contact on a collision course is given as Figure 6.

Procedure. Each subject was scheduled to perform one 2-hour test during each 24-hour period in the longer (i.e., 48-hour) runs (see Volume 2 for a description of scheduled times and conditions). Each trial was initiated, controlled, scored, and terminated by the computer. Six threatening contacts were displayed during each successive 30-minute period of the test. Threatening contacts occurred separately. The time a threatening contact remained on a collision course varied between 2 and 9 minutes. The minimum and maximum times between the presentations of successive threatening contacts were .1 and 10 minutes respectively (average, 5 minutes).

Results and discussion. Summary data for each subject in each condition are presented in Appendices C and D. No data were collected from the first team of subjects because the task was not fully operative at that time, and the task was not administered during the short runs for the third team. Data for nine subjects in the static condition are presented in Appendix C. The mean performance scores (percent of collision course remaining after detection) for Day 1 and Day 2 of the initial static exposure were 58.2 and 57.5, respectively. A *t*-test for correlated means showed this difference to be not significant ($t = -.20$; $df = 8$, NS).

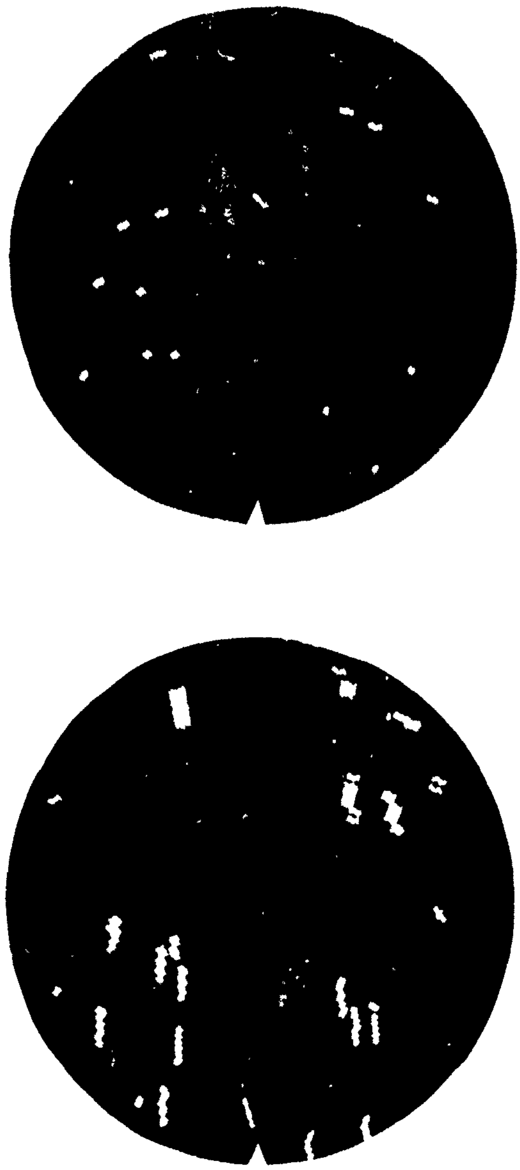


Figure 6. Simulated radar imagery during the Radar 2 *(collision avoidance)* task. (The top photograph is a 5-second time exposure showing the appearance of 14 contacts during a single radar sweep; the bottom is a 30-second time exposure of the appearance of 23 contacts as these appeared to move by discrete steps in 6 successive repaintings. All contacts are benign except that approaching the vertical display axis [0° bearing] at close range [display bottom]. The latter is an example of a threatening contact.)

The only data for motion conditions were for Low, 80 kt, SS3; Full, 80 kt, SS3; and Full, 40 kt, SS5 (Appendix D). The means for first- and second-day scores for all subjects who performed the task on both days were 59.8 and 61.7, respectively. A *t*-test for correlated means failed to show a significant difference ($t = .51$; $df = 12$, NS).

Figure 7 shows the change in performance from static to motion for those subjects from whom there is complete data. In all cases, data from the initial static exposure were used for calculating the change in performance from static to motion conditions. Moreover, Day 1 motion was compared to Day 1 static and Day 2 motion, to Day 2 static.

The subjects' performance in the Low, 80 kt, SS3 condition was slightly better than in the static condition in trials administered on successive days of exposure. There was virtually no difference in performance between the static and the Full, 80 kt, SS3 condition on either day. The two subjects who completed the Full, 40 kt, SS5 condition performed the task in a somewhat more efficient manner than they had previously in the static condition. None of the subjects who undertook the Radar 2 task during any motion condition reported or showed evidence of motion sickness during any trial.

Again, there was little in these results to indicate any deleterious effect of the 80 kt, SS3 motion upon radar monitoring performance. In both static and motion conditions, the subjects seemed equally able to make continual, complex perceptual judgments, which required sustained attention, memory, and pattern recognition. Moreover, there was no significant effect of exposure time (first versus second day) in either static or motion conditions.

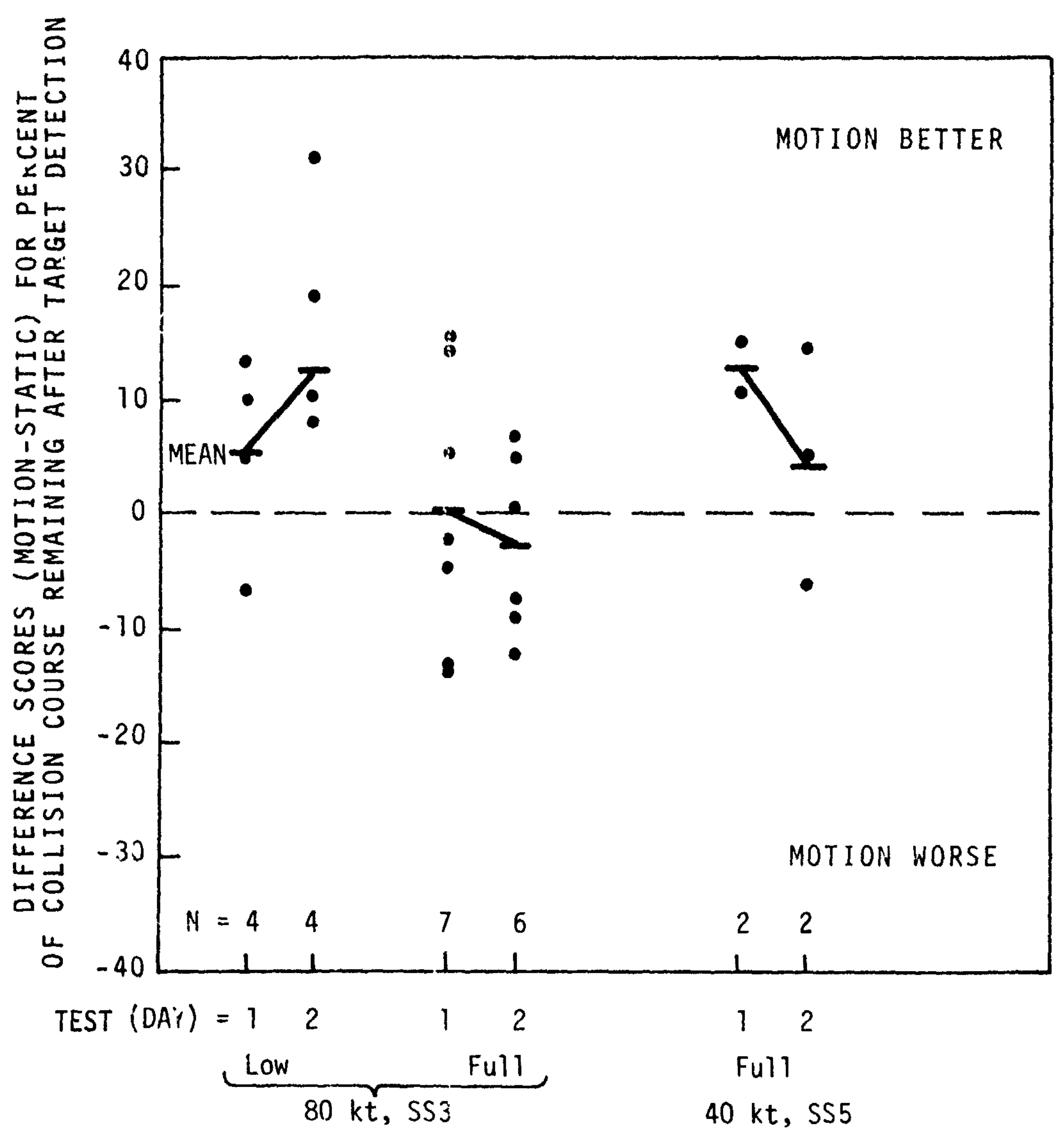


Figure 7. Difference in Radar 2 *(collision avoidance)* task performance between static and motion conditions on first and second days of exposure for all possible individual comparisons. (Horizontal bars indicate group mean difference levels.)

Cryptographic Decoding and Encoding

Rationale and approach. The cryptographic tasks were developed during Phase 1A of the program to meet the requirement for measuring subjects' motivation to perform routine work. That requirement evolved from the widespread belief that motion stress, leading to motion sickness, generally impairs motivation to work before it impairs the capability for work.

The tasks were designed to be self-paced and operationally relevant. They involved near-field visual search and character recognition. Performance on the tasks was proven sensitive to motion stress in the Phase 1A investigation (Jex, O'Hanlon, & Ewing, 1976).

The decoding part of the task was administered in tests beginning with the experimenter's command and continued until the subject signaled that he had completed the work or until 16 minutes had elapsed, whichever came first. The subject's activities during the task were as follows. He opened a sealed envelope containing (a) a coded message, and (b) a decoding matrix. The message consisted of 200 letters arranged in two columns of 10-letter "words." A typical message is shown below:

O F O J V J L J V U	K J V J L C V R W C
V R V J W J V U Q E	O E W U O B O B W J
V U V E V E Q B W U	K E O B Q C V U K J
O J V J V F Q F Q F	K F V U W C V J V U
L J L F Q R Q F V U	L F V U O J V C W J
V U O F V J O J V U	L F V F V J V C L C
W C V R V F V U K J	O J V R W J W C V U
Q R Q F Q F K J V U	V F W R Q F V F Q R
V U V J W J V U V F	V J W J W C L F V F
W C L C V U V R W J	V U L F O J Q F L F

The subject proceeded to decode each successive pair of code letters, reading left to right across columns using the decoding matrix. The body of the matrix was a 7 X 6 table containing single letters, numbers, symbols, or empty spaces in each of the 42 cells. The margins of the table were bordered by an additional row and column of different letters: Seven were aligned with respective rows; six with respective columns. An example of the decoding matrix and marginal characters is shown below:

	L	W	V	K	Q	O
F	A	B	C	D	E	F
R	G	H	I	J	K	L
J	M	N	O	P	Q	R
C	S	T	U	V	W	X
E	Y	Z	1	2	3	4
B	5	6	7	8	9	0
U	/	-		.		

Each pair of consecutive letters in the code message was used to read a single decoded character in the matrix. The first code letter was found in the top margin row; the second, in the side margin column; and the decoded character was found at the intersection of the identified row and column. In the example given above, the initial code letter pair, OF, yields a decoded letter F in the matrix; the second pair, OJ, yields R; and so on. The entire decoded message reads:

> FROM POSITION 34-00N 119-20W PROCEED TO MAKE A RUN
> FOR ACOUSTIC PRINT KEEP CHECK ON CONTACTS IN AREA

The subject transcribed the coded message, letter-pair by letter-pair, into its decoded form on a tablet page. At the end of the test he removed the page and sealed it along with the code message and matrix in another envelope. The subject's time to complete the decoding task was then recorded by the Test Administrator. The code message and the marginal characters on the decoding matrix were varied between trials for each subject.

The encoding part of the task was also administered in 16-minute tests. It was merely the reverse of the decoding part. That is, the subject was given an uncoded message and required to use the matrix to produce a coded message of the type described above.

Performance was scored as the mean minute-rate of correctly transcribing uncoded characters from code (decoding) or into code (encoding) in a single trial. Thus, a transcription rate score was a composite measure of both the accuracy and speed of transcription for that subject within a given trial.

Procedure. Each subject was scheduled to perform two tests of decoding and encoding, once during each 24-hour period of the longer (48-hour) runs and one test during the shorter (6-hour) runs. The two sections were administered before and after the navigational plotting task, about 40 minutes apart. Decoding was administered first. A new coded or uncoded message and a new code matrix were used on different tests by the same subject. Unused materials were kept in the lockbox and used materials were placed in the mail-drop bag for recovery by the Test Administrator at regular intervals.

Results and discussion. The mean transcription rate was calculated for each subject in each test under all static and motion conditions for both decoding and encoding tasks. These data are presented in Appendix E for the static sessions and Appendix F for the motion conditions. Summary data are provided for the mean of each subject's static runs and the mean for each motion condition. The data are further categorized as being obtained from day and night sleepers.

To evaluate the effects of the various motion conditions on cryptographic performance the differences between each subject's first run static scores (first and second tests) and corresponding motion scores were calculated. These difference scores are presented in Figure 8 for decoding, and Figure 9 for encoding.

It is apparent from the figures that there were no striking effects of motion on performance, except perhaps on Day 2 of Full, 40 kt, SS5, for encoding. In general, however, there were no systematic changes in mean performance levels with increasing motion severity, or with time of exposure to motion.

Two subjects performed the task while experiencing severe nausea. One (No. 47 in Medium, 80 kt, SS3) could perform only the decoding task before leaving the motion environment, but the other (No. 52 in Full, 60 kt, SS4) completed both cryptographic tasks. In spite of their condition, neither subject's transcription rate fell by more than three characters per minute in the motion condition, relative to his respective static score. The former subject showed the greatest relative drop in transcription rate during motion, but even he was performing at better than 80% of his static level.

These limited data suggest that performance of self-paced tasks requiring near-field visual search and character recognition would be little impaired for well individuals

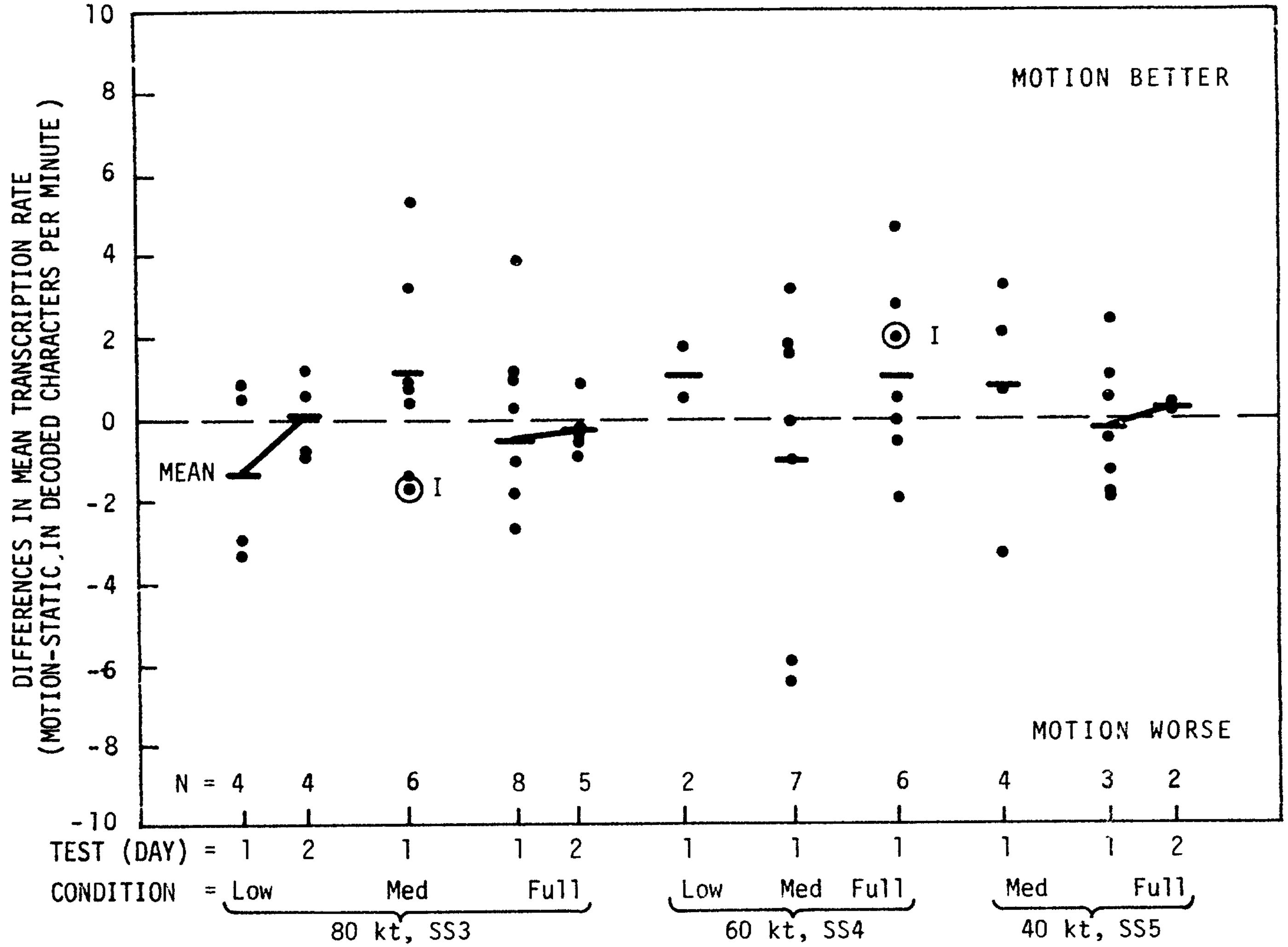


Figure 8. Difference in cryptographic decoding task performance between static and motion conditions on first and second days of exposure for all possible individual comparisons. (Horizontal bars indicate group mean difference levels.)

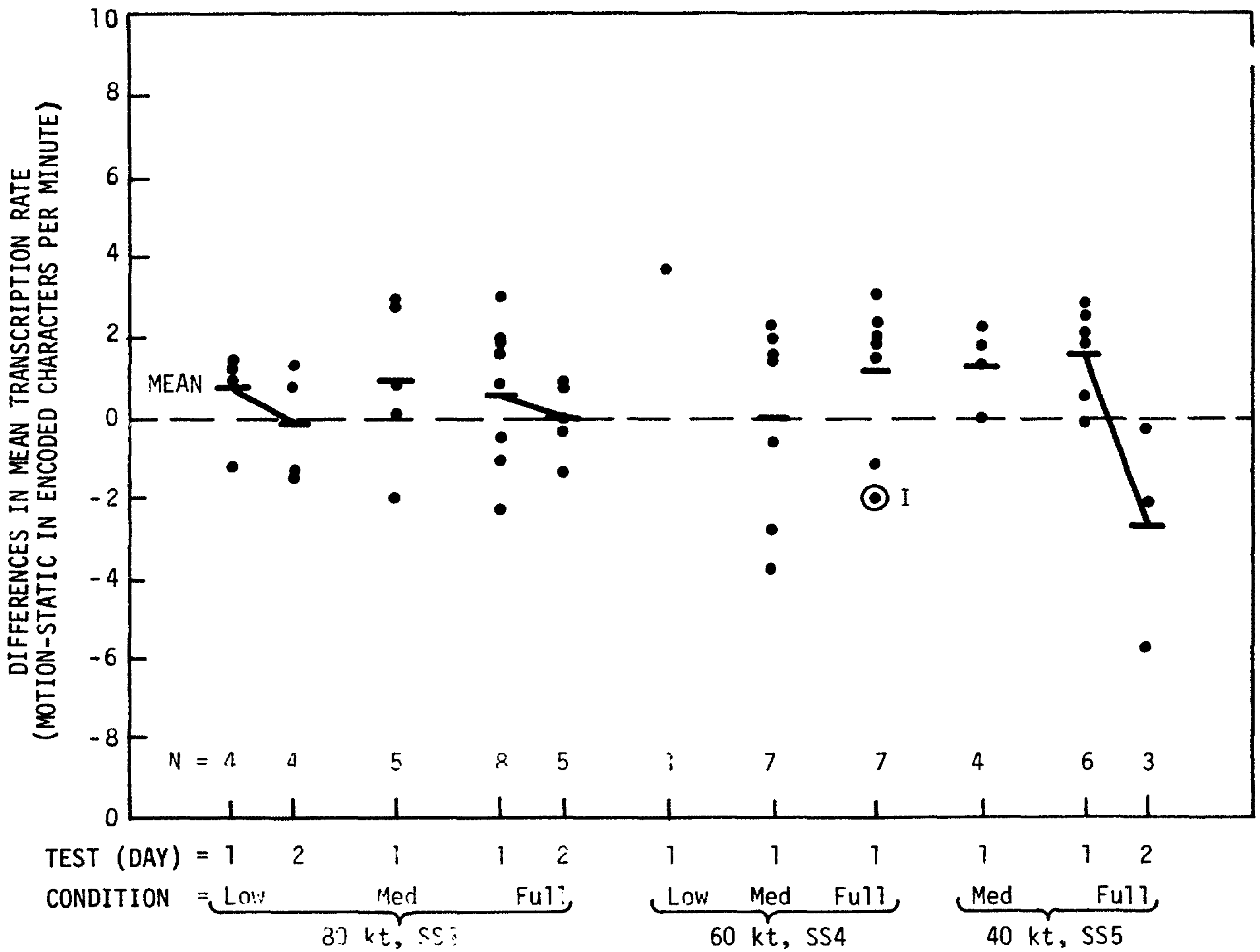


Figure 9. Difference in cryptographic encoding task performance between static and motion conditions on first and second days of exposure for all possible individual comparisons. (Horizontal bars indicate group mean difference levels.)

exposed to SES motions, except possibly after 24 hours of exposure to very severe motion (e.g., 40 kt, SS5). Even those sick individuals who are willing to work at such tasks seem to perform in a reasonably proficient manner.

Navigational Plotting

Rationale and approach. The plotting task was closely modeled after the actual task performed by the Operations Specialist, acting as the plotter of radar returns on the bridge of U.S. Navy vessels. In many ways it was the most complex and realistic task in the test battery. It simultaneously tested several cognitive functions including attention, perception, memory, and fine motor control under time pressure dictated by a rapid rate of information transmission.

The Test Administrator conducted the task for two subjects, performing in parallel but independently, in the moving and static cabins, respectively. The subjects' task involved plotting their own-ship's course and the periodically reported positions of radar contacts on a nautical map overlay. Own-ship's starting position, speed, and heading were given by the Test Administrator at the beginning of the task. The subjects then proceeded to plot an initial course, placing time ticks on the intended line of travel at distances depending upon given speed (i.e., at positions he should reach at 1.5-, 1.0-, and 3.0-minute intervals when traveling at 80, 60, or 40 knots, respectively). Beginning with the first transmission and continuing at the indicated intervals, the Test Administrator announced the ranges and bearings of the radar contacts initially located within ±15° of the intended course. The rate of transmitted contacts depended upon the indicated ship speed: One contact per transmission was reported for 60 knots; alternately, one and two contacts were reported on successive transmissions at 80 knots; and three contacts were reported each time at 40 knots. These contacts were not random in position, but rather arose in clusters of three to four to simulate radar returns from the same moving or stationary target in the water. Each target was identified in transmissions by a corresponding code word from the standard military phonetic alphabet, i.e., alpha, bravo, charlie, etc.

Midway through the test, a change in own-ship's heading was indicated by the Test Administrator to increase task complexity by requiring the subject's reorientation in the plotting space. Information regarding course change was given in lieu of one reported contact. Therefore, by the end of the test the subject should have plotted the positions of 29 contacts and the course change. After the last transmission, the subject was allowed one normal plotting interval to complete his work. Then he was required to cease that activity. Finally, the subject removed the overlay from the plotting board and placed it in the mail-drop bag for later retrieval and scoring by the Test Administrator.

Each plotting record was scored to yield a single proficiency score, i.e., the average distance error (in miles) between plotted contact positions and corresponding "true" positions on the map, relative to own-ship's position and heading at the time of data transmission.

Apparatus and procedure. Each subject was scheduled to perform the task once during each 24-hour period of the longer (48-hour) and once during the shorter (6-hour) missions. He employed a plotting board (28 X 36 inches), a drafting arm, a U.S. Coast and Geodetic Survey map of the Santa Barbara Channel (approximately 7,000 square miles at a reduction of 1:863,000), and translucent vellum overlays. Communication with the Test Administrator was achieved using the usual intercom system. A picture of a subject performing the task is given in Figure 10.

In all, 18 equally difficult versions of the task were available including 6 for each of the three basic ship-speed/sea-state conditions of motion simulation. No subject received the same version twice.

Results and discussion. The results obtained from all subjects in the static condition are summarized in Appendix G;

Figure 10. Simulation of Navigational Plotting Task showing the subject working at the plotting board.

for all subjects in various motion conditions, in Appendix H. The results from 9 tests (5 tests from three subjects in static and 4 tests from three subjects in motion) were unscoreable because the subjects plotted an erroneous course which eventually ran off the map. Once (for Subject 47 in the Medium, 80 kt, SS3 condition) this error was made while the subject was experiencing severe nausea due to motion sickness. Otherwise, there was no apparent association with the experimental treatment or subject's condition at the time of testing.

As for the tasks described previously, the effects of motion on average plotting error were evaluated from the difference scores measured between each subject's initial scoreable first- and second-day static tests and corresponding tests in each motion condition. These difference scores are shown in Figure 11.

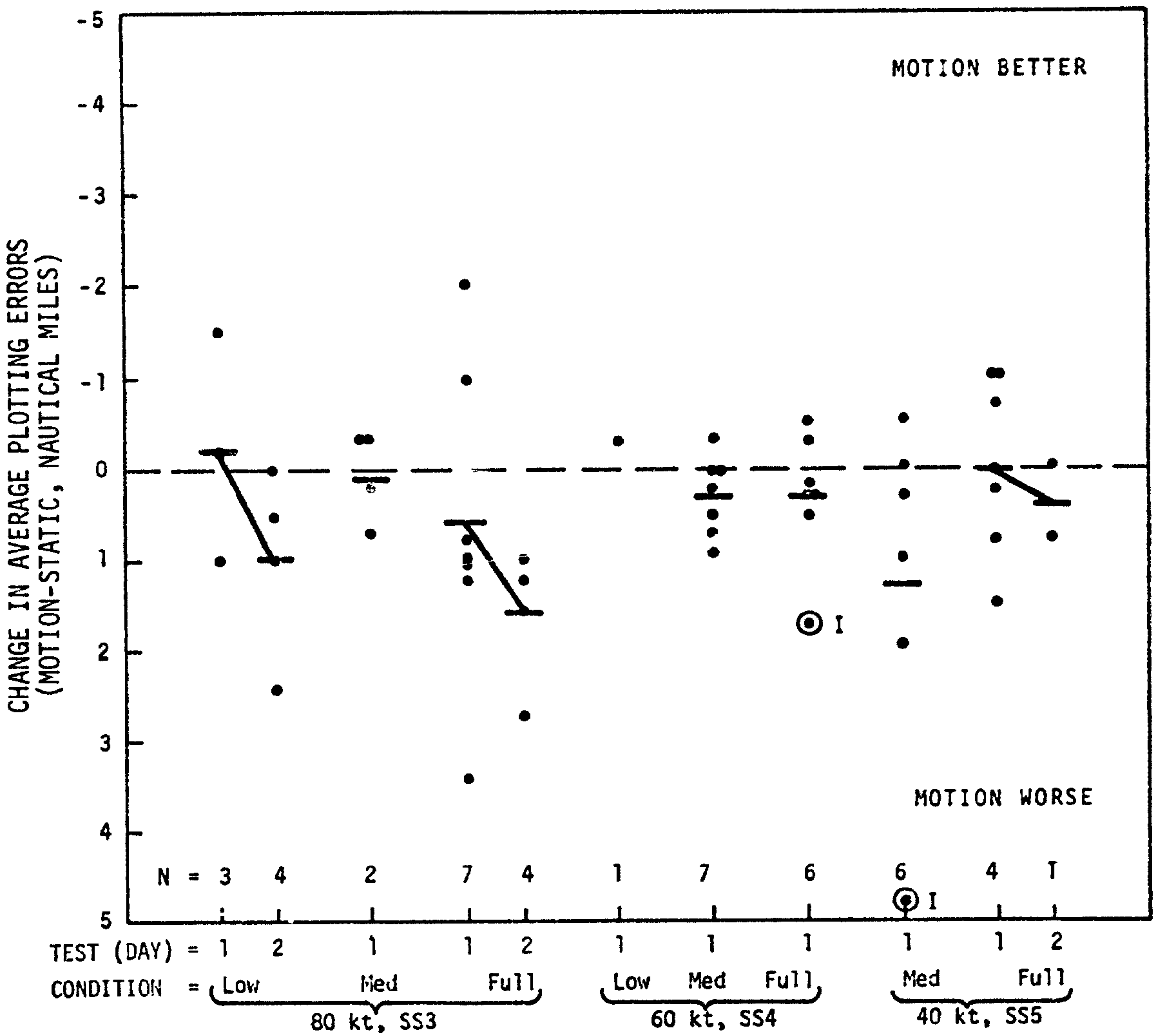


Figure 11. Change in average plotting errors from static to motion on first and second days of exposure for all possible individual comparisons. (Horizontal bars indicate mean changes. The letter "I" indicates the subject was sick at the time of test in the motion condition.)

The results shown in Figure 11 are somewhat ambiguous. For while it was true that no mean change in performance measured in any condition was statistically significant, several results suggested that task performance was sensitive to motion effects. There was a drop in performance proficiency, in every case, from the first to the second exposure day. Moreover, both of the subjects who experienced motion sickness during the task failed to complete that assignment. In the Full, 60 kt, SS4 condition, Subject 52 worked for about 25 minutes, yielding a somewhat degraded error score, and then spontaneously ceased all task-related activity. He complained of severe nausea before and during the task and vomited 22 minutes after it was over. In the Medium, 40 kt, SS5 condition, Subject 59 worked for only 11 minutes and yielded the worst recorded score. He then vomited and immediately requested to leave the moving environment.

On the basis of these limited data one would have to tentatively conclude that individuals suffering from motion sickness cannot be expected to perform similar tasks with acceptable proficiency.

Visual Acuity Test

Rationale and approach. Unimpaired near-field visual acuity is critical for the performance of many Navy tasks. Yet intense whole-body vibration near the upper limit of the anticipated SES frequency spectrum can degrade visual acuity (Hornick, 1972). In Phase 1A of this research program, visual acuity was unaffected by motion: Subjects were always able to read characters subtending a visual angle of as little as 8.5 by 5.0 minutes of arc from normal reading distances (Jex et al., 1976). Because motion in the present investigation was more intense, particularly with regard to acceleration imparted at higher frequencies, it seemed prudent to further evaluate the effects of simulated SES motion on the subjects' visual acuity.

In this approach, the subject read aloud from textual material which was fixed to the cabin wall. He held his head at a constant distance from the text (x-axis) but his head was free to move vertically (z-axis) with the motion. The text was divided into 17 sequentially numbered sections. Character size was constant within sections, but varied in discrete steps between sections. At 91 cm (36 inches), the visual angle subtended by the largest character size was 11.28 minutes of arc; the smallest was 2.82 minutes of arc.

The subject's task was to read the section with the smallest visible character size, and state the section's identifying numeral to the Test Administrator. That score was recorded for later determination of visual acuity, as the threshold visual angle required for character discrimination.

Apparatus and procedure. Textual material was presented in a wall-mounted, spiral-bound notebook containing 28 different versions of the test, identified by corresponding tab indices. An example of one version is shown in Figure 12. Different versions of the test were administered on separate trials. A trial began when the Test Administrator specified the tab index for the appropriate test in the notebook over

No. 2.

17 -	against evil—as the object of our research. "Fun" non- rationality is less of a social problem and therefore less
16 -	even after his arm had been broken, the gang let the battle go on until he finally pounded Cheese-Face to a senseless
15 -	tioning of their fundamental personality structure. In times of crisis violent leaders are liable to act on impulses fully
14 -	from each panting breath. There is never enough to drink when it takes precious fuel to melt each drop of water.
13 -	is a story of my own making and, since the story was orig- inally published about thirty-five years ago, my discussion
12 -	and the weeks spent on the approach march with its ac- companying sunburn, blisters, injuries and sickness. From
11 -	recounts the steps he takes, after he has left the city and married for money in the country, in arranging for a troupe
10 -	is a story of my own making and, since the story was orig- inally published about thirty-five years ago, my discussion
9 -	fury recounted in the book, while the nine white cranes are imported from memories of the morning after a storm
8 -	*Statement.* It so turns out that if he hadn't resigned, he'd most likely have been dismissed a year later, for the entire
7 -	branch of the organization by which he had been employed was discontinued But the point is that when he quit he had
6 -	ously put a great strain upon him making him imperious even though he also had an almost pathetic desire to be
5 -	In "The Cowboy and the Lady" the late Gary Cooper said to the female I aims ma am to be high regarded It
4 -	to do my work and settle to it immediately, all of the moving up stress lifts off once I arrive even though my
3 -	All told that complex composed a subpersonality within myself so that one was, as it were "hearing a call" of
2 -	for granted Hence many things however vehemently they were said could be received like water off a duck's back,
1 -	precise function performed by them at different times and in different places In some cases they might serve to draw

Figure 12. One version of stimulus material used in the visual acuity test.

the intercom. The subject then opened the notebook to the indicated page and positioned his head at a distance of 91 cm from the wall, using a tape measure fastened below the notebook. He then read what seemed to him to be the smallest legible print. If he read with 100% accuracy he was instructed to read the section displaying the next smallest print; if he read inaccurately, he was told to read the section displaying the next larger print. The Test Administrator determined the subject's reading accuracy from his copy of the text. When the former determined the section could be read in its entirety by the subject, he recorded the identifying section numeral and stopped the test. Tests were administered at the beginning and end of every working period in both the long and short missions.

Results and discussion. Individual results obtained during static sessions are summarized in Appendix I; results obtained during the various motion conditions, in Appendix J. In each table the data correspond to the visual angle (in minutes of arc) subtended by the smallest legible print for that particular subject and trial (i.e., near-field visual acuity threshold).

The analysis of respective motion effects on visual acuity was performed by comparing individual average static threshold values obtained in tests at the beginning and end of work periods on the first and second days of exposure, with comparable values measured during the different motion conditions. Figure 13 shows the results of the comparisons as individual changes in visual acuity.

The figure shows that the mean change in visual angle was in the direction of increasing visual acuity threshold in every motion condition, i.e., larger character size was required for correct reading in every motion condition. However, the decrease in visual acuity during motion was not large; mean changes never exceeded .7 minutes of arc.

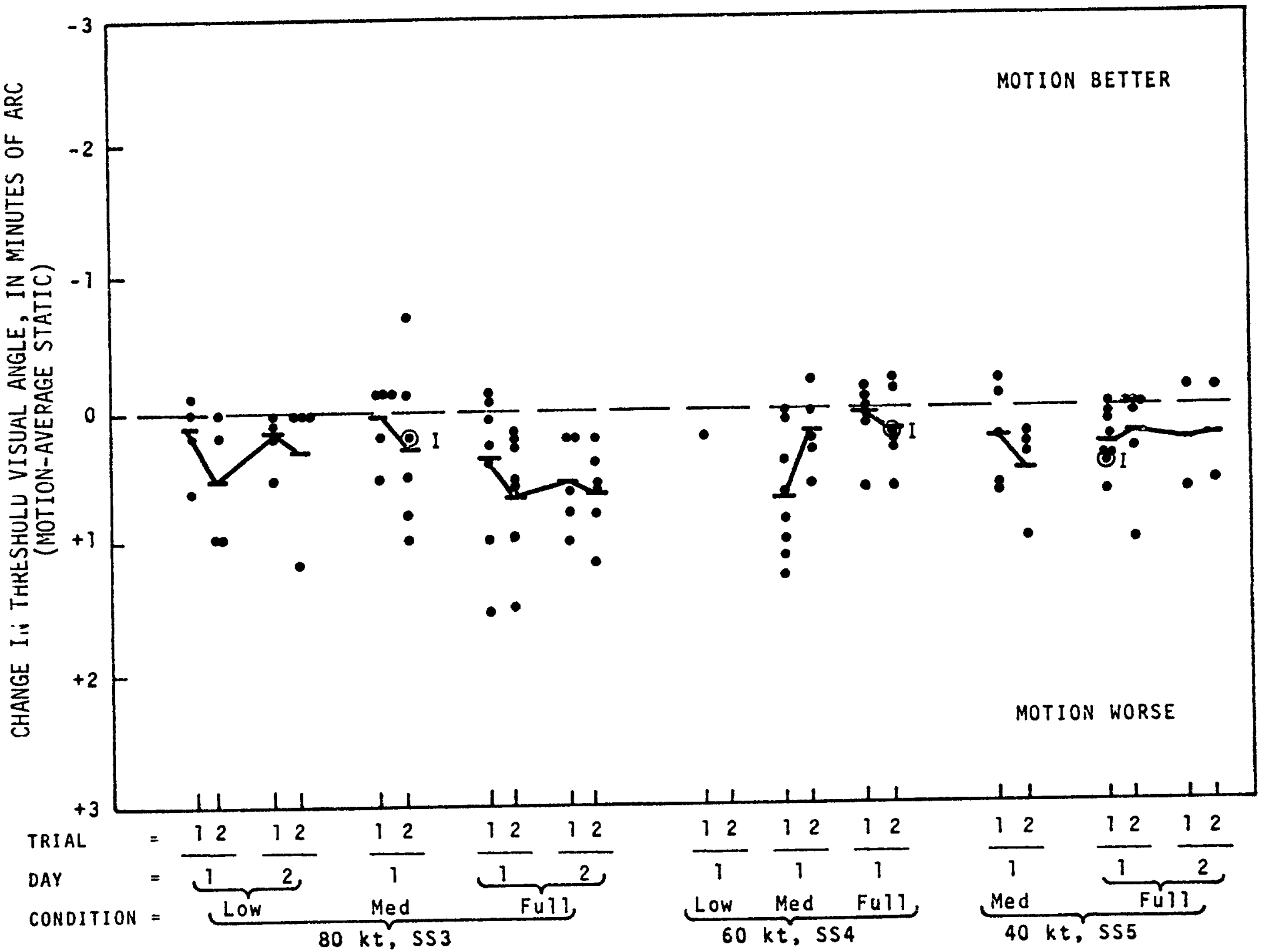


Figure 13. Change in threshold visual angle from average static to motion conditions on trials administered at beginnings (1) and ends (2) of work periods and on first and second days of exposure for all possible individual comparisons. (Horizontal bars indicate mean changes. Letter "I" indicates subject was sick at time of test in motion condition.)

The significance of the mean change in threshold visual angle was assessed for each condition by a t-test for correlated means. Where the same subject provided more than one score for a given static or motion test due to repeated exposures, the average of his scores was used in the analysis. Significant results are summarized in Table 4.

TABLE 4

SIGNIFICANT RESULTS OBTAINED IN STATIC VERSUS MOTION COMPARISONS OF THRESHOLD VISUAL ANGLE

CONDITION	TEST SEQUENCE	DAY	VISUAL ANGLE (MINUTES OF ARC) MEAN MOTION	MEAN STATIC	MEAN DIFFERENCE	t	df	p<
Full, 80 kt, SS3	2	1	4.34	3.71	.63	4.40	7	.01
Full, 80 kt, SS3	1	2	4.05	3.53	.52	3.44	4	.05
Full, 80 kt, SS3	2	2	4.16	3.56	.60	4.46	5	.01
Med., 60 kt, SS4	1	1	4.20	3.57	.58	3.79	7	.01
Med., 40 kt, SS5	2	1	4.08	3.65	.43	2.47	3	.10
Full, 40 kt, SS5	1	1	3.86	3.63	.23	3.84	4	.02

The results of the analysis indicate that the mean changes in threshold visual acuity were generally significant in all motion conditions more severe than Full, 80 kt, SS3. Only the results from the Full, 60 kt, SS4 condition were in opposition to this tendency. This exception notwithstanding, one might expect similar degradation in visual acuity in similar SES motion conditions. However, the fact that no mean change was of particularly large amplitude indicates that no special provision need be made for the display of characters aboard the eventual large-scale SES. Application of the MIL-STD-1472A criteria for minimum character size (e.g., 4.3 mm at a viewing distance of 91 cm, producing a visual angle of about 16 minutes of arc) should be sufficient for ensuring the legibility of displayed characters in similar SES motion conditions.

ASSESSMENT OF SLEEP

Electrophysiological Recordings

Rationale and approach. In comprehensive research aimed at evaluating the habitability of potentially adverse environments, a basic question is whether or not the situation allows the individual to obtain adequate sleep for the maintenance of effective performance levels and health. Any environment which significantly impairs the quantity or quality of sleep must be judged uninhabitable on a long-term basis. On the other hand, even environments which stress the waking individual, or impair his performance to a limited degree, may be safe for prolonged habitation, if he is able to recover from stress and fatigue during sleep.

Objective means for evaluating the quantity and quality of sleep are well developed and widely applied. The usual approach (Williams, Karacan, & Hursch, 1974) involves the recording and analysis of the simultaneous electrophysiological activity of the brain, eyes, and skeletal musculature. Respectively, those recordings are called the electroencephalogram (EEG), electrooculogram (EOG), and electromyogram (EMG). The usual procedure involves recording electrical potentials from surface EEG electrodes over the scalp, EOG electrodes at the corners (lateral canthi) of the eyes, and EMG electrodes under the chin (over the platysma muscles). Typically, these recordings are interpreted visually and scored manually, according to standard procedures, to yield measures of time spent in each of the different stages of sleep. The latter include Stage 1 (S1, drowsiness); Stage 2 (S2, light sleep); Stages 3 and 4 (S3, S4, deep sleep, slow-wave sleep); and Rapid-Eye-Movement Sleep (SREM), when dreaming usually occurs. Periods of wakefulness (SA) during the sleep period are also scored according to this procedure.

In the present investigation the attempt was made to completely record, on magnetic tape, EEG, EOG, and EMG from all subjects, in every sleep period in both moving and static cabins, during every scheduled 48-hour mission. It is hoped that the Naval Aerospace Medical Research Laboratory Detachment (NAMRLD) will be able to apply a recently developed computer program to automate the sleep scoring procedure, thereby permitting the analysis of the total data base. It was never anticipated that the total analysis could be accomplished by the conventional manual scoring method within practical time or budget constraints. Nonetheless, the attempt was made to apply the conventional approach in an analysis of selected recordings to yield representative motion versus static comparisons for a preliminary assessment of the motion's effect on sleep.

Apparatus. EEG electrodes (silver, 9 mm cup-type) were affixed to the scalp with collodion for monopolar recording between the right parietal area and the left mastoid bone. EOG electrodes were attached by adhesive disks at the lateral canthi of the eyes in a monopolar configuration referenced to the left mastoid, and EMG electrodes were similarly attached under the chin in a bipolar configuration. Raw EEG, EOG, and EMG signals directed through respective 48-inch leads to separate differential preamplifiers (gain, 10^4; common-mode rejection, 110 db; and time constant, .3 second) and second-stage isolation amplifiers (gain, 10^1). The system's frequency response was essentially linear from .5 Hz to 30 Hz (EEG and EOG) or 120 Hz (EMG). Response was -3 db at the respective upper limits and declined by -25 db per octave above. In addition, EMG signals were passed through a very sharp, 60 Hz notch filter (-40 db). This apparatus was replicated in special "biopacks" mounted on the wall adjacent to the bunks in both the moving and static cabins. The biopacks were connected by cables to buffer amplifiers (gain, 10^0) in the control room patch panel. Signals from these were directed to recording equipment including four-channel (static cabin) and eight-channel (moving cabin) strip-chart recorders, and NAMRLD's tape recording system.

Sleep scoring was accomplished according to the standard method of Rechtschaffen and Kales (1968). Sleep stages and interruption of sleep were scored by consecutive 30-second epochs. The scores were coded, keypunched, and processed using a PL/1 program on an IBM 360/75 computer system. The following sleep variables were delivered as the system outputs:

Time in Bed (TIB). The elapsed time spent attempting to sleep (Williams et al., 1974).

Sleep Latency. The elapsed time from the beginning of TIB until the first occurrence of S2 sleep.

Sleep Period Time (SPT). The elapsed time from the end of sleep latency until awakening (Williams et al., 1974).

Total Sleep Time (TST). SPT minus awake time occurring within SPT (Williams et al., 1974).

Sleep Stage Percents. Percentages of SPT respectively spent in S1, S2, S3, S4, SREM, and SA.

Sleep Stage Amounts. Number of minutes during SPT spent in each sleep stage.

TST : TIB (TST/TIB). A sleep efficiency index sensitive to sleep disturbance (Williams et al., 1974).

SREM ÷ (SREM + S1) Index. A sleep index sensitive to sleep disturbance (Schmidt & Kaelbling, 1971).

Stage Shifts. Number of changes of sleep stage during SPT (Williams et al., 1974).

Mean Cycle Length ($\overline{CL}$). Mean length of uninterrupted sleep cycles during SPT, measured from the onset of SPT until the initial occurrence of S2 following an SREM period. The sleep stage content of each cycle was also printed for inspection and analysis.

Procedure. Electrodes were attached to the subjects who were first to retire in the moving and static cabins (usually the day-sleepers) prior to the beginning of the scheduled

48-hour run. Those subjects were allowed to retire at times of their choosing between 1100 and 1230 hours. They connected the electrodes to the biopack and were not disturbed by the Test Administrator until 3 minutes prior to the scheduled arousal time (2000 hours). If they awakened before that time, they were allowed to disconnect their electrodes but remain in the bunk. The subjects removed the electrodes themselves. Approximately 1-1/2 hours before the second member was to retire, the Test Administrator entered his cabin and attached the electrodes. For attaching electrodes in the moving cabin, the cabin motion was stopped long enough to admit the Test Administrator and permit him to attach the parietal electrode with collodion (usually less than 15 minutes), then motion was resumed while the other electrodes were applied. When this was accomplished, the motion was again stopped for about 5 minutes to permit the Test Administrator's exit.[3] Following this, the second subject retired (between 2300 and 0030 hours) and electrophysiological recordings resumed. Again, the subjects were left undisturbed until 3 minutes prior to their scheduled arousal time (0800 hours). Electrode attachment and EEG recording were accomplished on the second day in this latter manner for the day-sleepers, then later for the night-sleepers.

Results and discussion. Twenty-one separate and complete sleep records, obtained from 11 subjects, were manually scored. Each motion record was relatively free of motion artifacts, as verified from simultaneous tracings of electrophysiological and heave acceleration signals.

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[3] It may be important to note that Test Administrator personnel were always able to successfully perform the delicate task of applying electrodes in motion. Though not planned, this constituted an additional test of the effect of simulated SES motion on human performance. In the Test Administrators' opinions, the task was more difficult in motion, particularly in the higher sea state. However, that they were able to perform the task at all indicates that tasks demanding a similarly high degree of precise hand/eye coordination can be eventually accomplished by skilled operators, even under relatively severe motion conditions.

The general composition of scored sleep, in both static and motion conditions, was slightly disturbed. While sleep period times (SPT) were normal, they contained greater than normal percentages of S1 (drowsiness) and SA (awake) time, and less than normal percentages of slow-wave sleep (S3 and S4) and dreaming sleep (SREM). Although these results indicated that the subjects may not have been fully acclimatized to the cabin environments and experimental protocol, they should not invalidate a static-motion comparison.

Records were available from 7 subjects in both static and motion conditions, allowing a within-subject statistical test of the effect of motion upon the electrophysiological correlates of sleep. Additionally, records were available from 4 subjects whose sleep was interrupted by motion sickness (vomiting or severe nausea) during time in bed (TIB). One of these subjects, on a separate occasion, also provided a record of sleep subsequent to severe nausea.

The statistical test of the effect of motion upon sleep suggested that sleep was unimpaired during exposure to moderately intense SES motion. A description of the subjects and conditions used for this comparison is presented in Table 5. Static records were uniformly obtained from the second day of each subject's first static run, allowing each subject one static sleep period during which to acclimatize to the cabin environment and experimental protocol. Motion records were primarily obtained from variations of the 80 kt, SS3 condition, with the exception of one record from the Full, 40 kt, SS5 condition.

A computer-graphics summary of a portion of the static-motion comparison is presented in Figure 14. Appropriate *t*-tests indicated that neither SPT nor the percentages of SPT spent in the various sleep stages or awake were significantly affected by the motion conditions encountered. The observation in Phase 1A that percent SREM was significantly diminished in

TABLE 5

DESCRIPTION OF SUBJECTS AND CONDITIONS FOR A COMPARISON OF SLEEP OBTAINED UNDER STATIC AND MOTION CONDITIONS

		STATIC		MOTION	
SUBJECT	SLEEP SCHEDULE	RUN SEQUENCE	DAY	CONDITION	DAY
49	N	1	2	Medium, 80 kt, SS3	1
52	N	1	2	Medium, 80 kt, SS3	1
50	D	1	2	Full, 80 kt, SS3	1
48	D	1	2	Full, 80 kt, SS3	1
40	N	1	2	Full, 80 kt, SS3	2
61	N	1	2	Full, 80 kt, SS3	2
39	N	1	2	Full, 40 kt, SS5	1

motion was not replicated. There was a large increase, however, in the variability of time spent awake ("Sleep Stage" A in the figure). Three other sleep parameters not represented in the figure were affected by motion: Absolute time spent in S1 (drowsiness) was less during motion (39.2 versus 61.1 minutes: $t = 2.60$, $df = 6$, $p < .05$); sleep cycle length was longer during motion (121.0 versus 101.4 minutes: $t = 3.33$, $df = 6$, $p < .05$); and there were fewer stage shifts in the motion condition (92.6 versus 118.6: $t = 3.60$, $df = 6$, $p < .05$).

Sleep disturbance is typically characterized at least by decreased SPT and percent SREM, increased percent SA, and an increased frequency of awakenings. None of these changes were observed in the static-motion comparisons described above. The changes that were observed are not indicative of sleep disturbance. Therefore, these limited results suggested that the sleep of subjects who were not at the time suffering from motion sickness was generally unaffected by motion. The following results, however, demonstrated dramatic changes in the sleep of certain subjects who suffered from severe motion sickness at the times recordings were made.

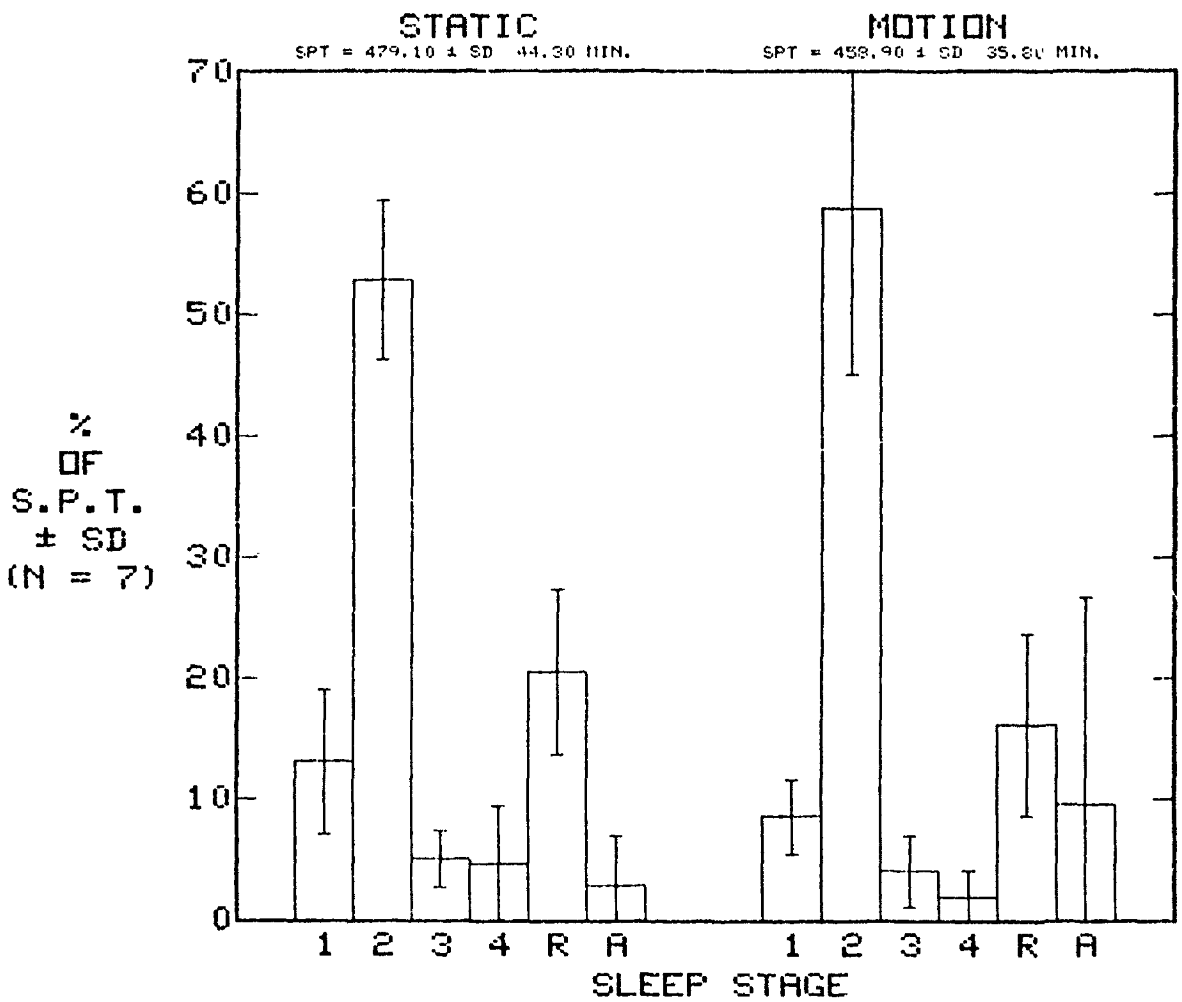

Figure 14. Computer-graphics summary of percentage time (M±SD) spent in each sleep stage and awake by seven subjects in both static and motion conditions.

Subjects 44 and 47 each slept normally during the second day of their first static run. This can be observed in the sleep profiles presented in Figures 15 and 16, respectively. In both cases, the normal transition from awake to slow-wave sleep occurred at the beginning of the sleep period, and slow-wave sleep dominated the first half of the sleep period. Subsequently, the normal alternation ($\overline{CL}$ of approximately 90 to 100 minutes) between slow-wave sleep and SREM occurred, with SREM dominating the latter portion of the sleep period. As normally found, S2 (light sleep) was evenly distributed throughout the sleep periods, accounting for about one-half of SPT.

Subject 44 displayed a normal sleep pattern during the Medium, 80 kt, SS3 condition (Run 440) until early, spontaneous awakening occurred at 1638 (Figure 15). He reported nausea while still in the bunk, vomited after arising, and finally withdrew from the motion condition at 1807.

Subject 47 generated virtually no slow-wave sleep during the Full, 60 kt, SS4 condition (Run 446, Figure 16). He remained primarily in light sleep (S2) with one interpolated period of wakefulness. At 1642 he awoke spontaneously, reporting severe nausea. He remained awake for the remainder of the run which was terminated at 2225 due to a simulator drive system failure.

Subject 47 also became sick during a second exposure to the same condition (Run 451) and in the Low, 60 kt, SS4 condition (Run 454). His sleep profiles on those occasions were similar to that described above. Subject 60 also became sick in the bunk. He obtained only 54 minutes of intermittent light sleep (S2) before finally awakening to experience severe nausea and vomiting during Full, 60 kt, SS4 (Run 550). On these occasions, Subjects 44, 47, and 60 produced far less than normal amounts of slow-wave sleep. On the average, their slow-wave sleep constituted only 8.9% of the total as compared

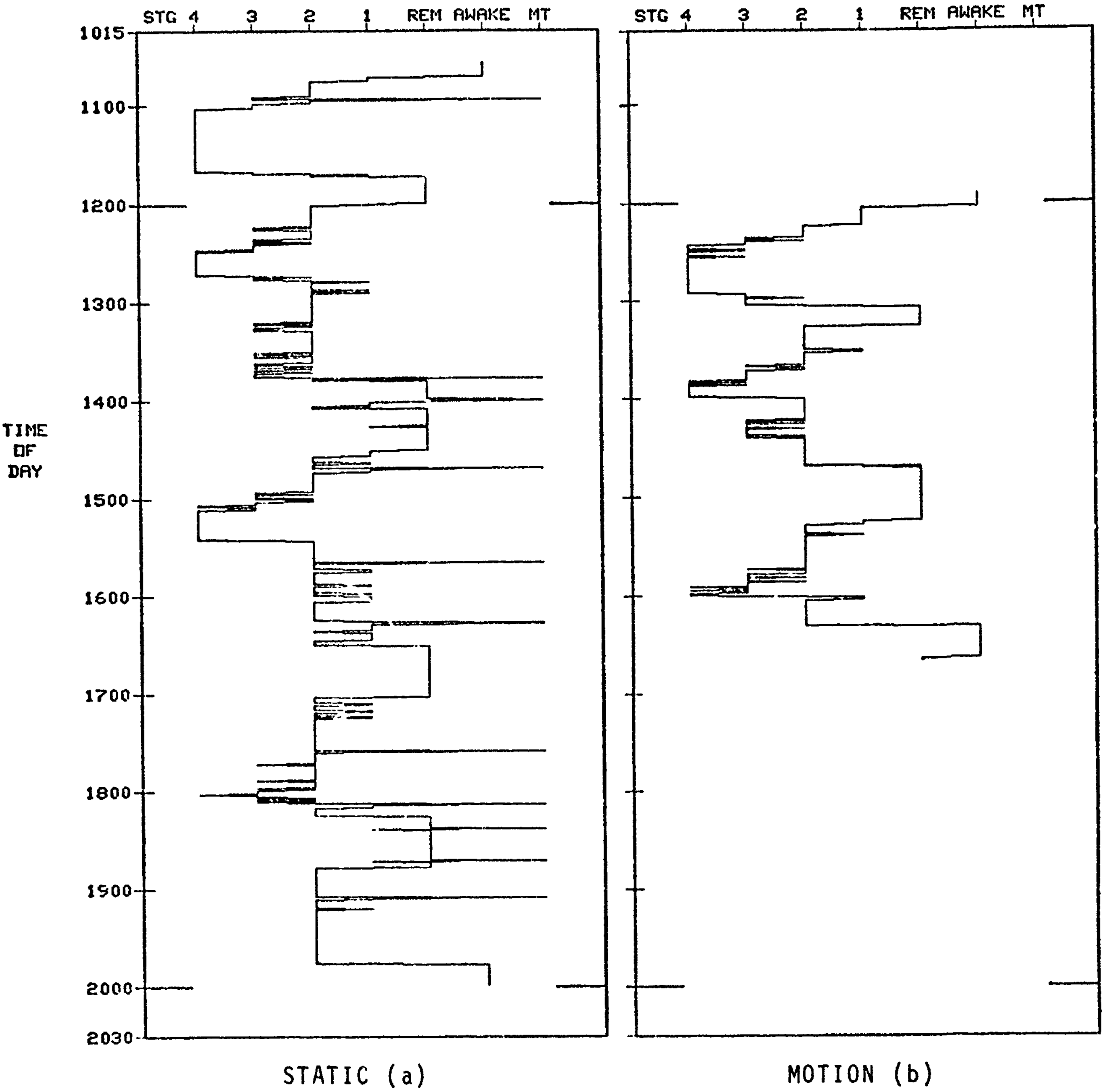

Figure 15. Sleep prints of Subject 44 in the static (a) and Medium, 80 kt, SS3 (b) conditions.

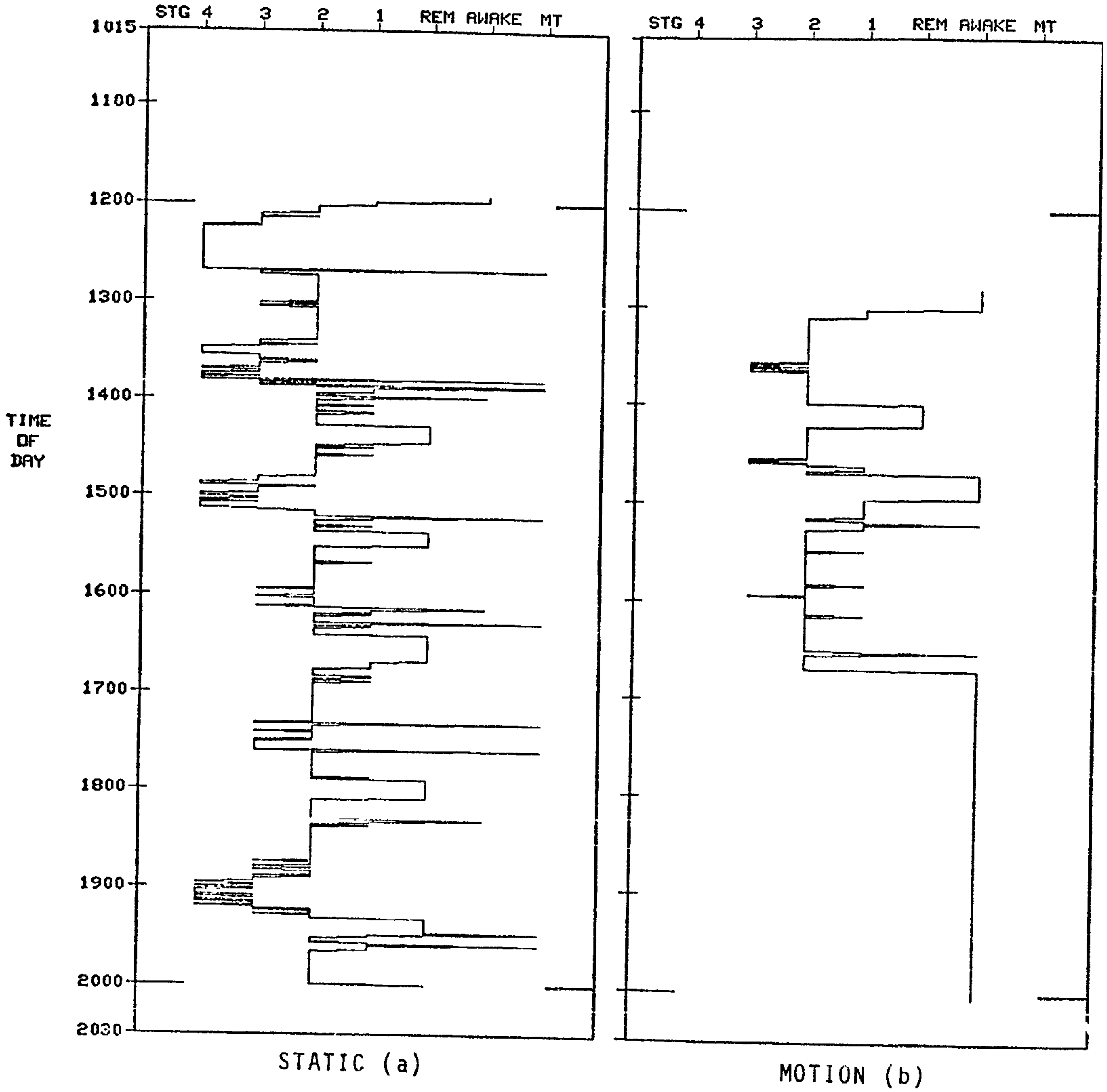

Figure 16. Sleep prints of Subject 47 in the static (a) and Full, 60 kt, SS4 (b) conditions.

to the normal 21%. Moreover, they were deprived of sleep by motion sickness, showing an average SPT of only 214 minutes versus the normal 425 minutes (Williams et al., 1974). On another occasion, motion sickness virtually prevented Subject 46 from sleeping during Medium, 80 it, SS3 (Run 455). He generated only 2.5 minutes of light sleep after retiring at about midnight, then terminated due to motion sickness at 0059.

Recent reviews of motion sickness literature fail to mention any comparable cases of individuals who awakened from sleep and either immediately or shortly thereafter experienced severe motion sickness while still in a reclining posture (Money, 1970; Reason & Brand, 1975). Thus, these results may indicate an unusual property of SES motion for disturbing the sleep of particularly sensitive individuals.

Subject 46 produced another interesting sleep pattern. His sleep record from the Low, 60 kt, SS4 condition (Run 453) represented the only recorded occurrence of sleep following reported nausea (Figure 17). At 2313, the subject reported mild nausea that he felt was related to the preceding cessation of motion (2248-2253) for electrode application. He retired at 2354, reported nausea in the bunk at 0116, and arose. At 0145 he reported continuing nausea. At 0219 he reported that he was "feeling better," retired again, and slept well. When awakened by the Test Administrator at 0800, he had obtained 320 minutes of sleep, of which 20.18% was slow-wave sleep (S3 and S4) and 14.06% was SREM (Figure 17). Slow-wave sleep dominated the first portion of the subject's sleep period, while SREM dominated the last portion, as expected, for undisturbed sleep. Although SPT and the percent of dreaming sleep (SREM) were below expected levels, 425 minutes and 28%, respectively, it may be conjectured that the subject would have obtained nearly normal sleep if not awakened by the Test Administrator. In any case, this subject reported no symptoms of motion sickness within the hour between awakening and motion termination, thus his sleep may have been associated with recovery from motion sickness.

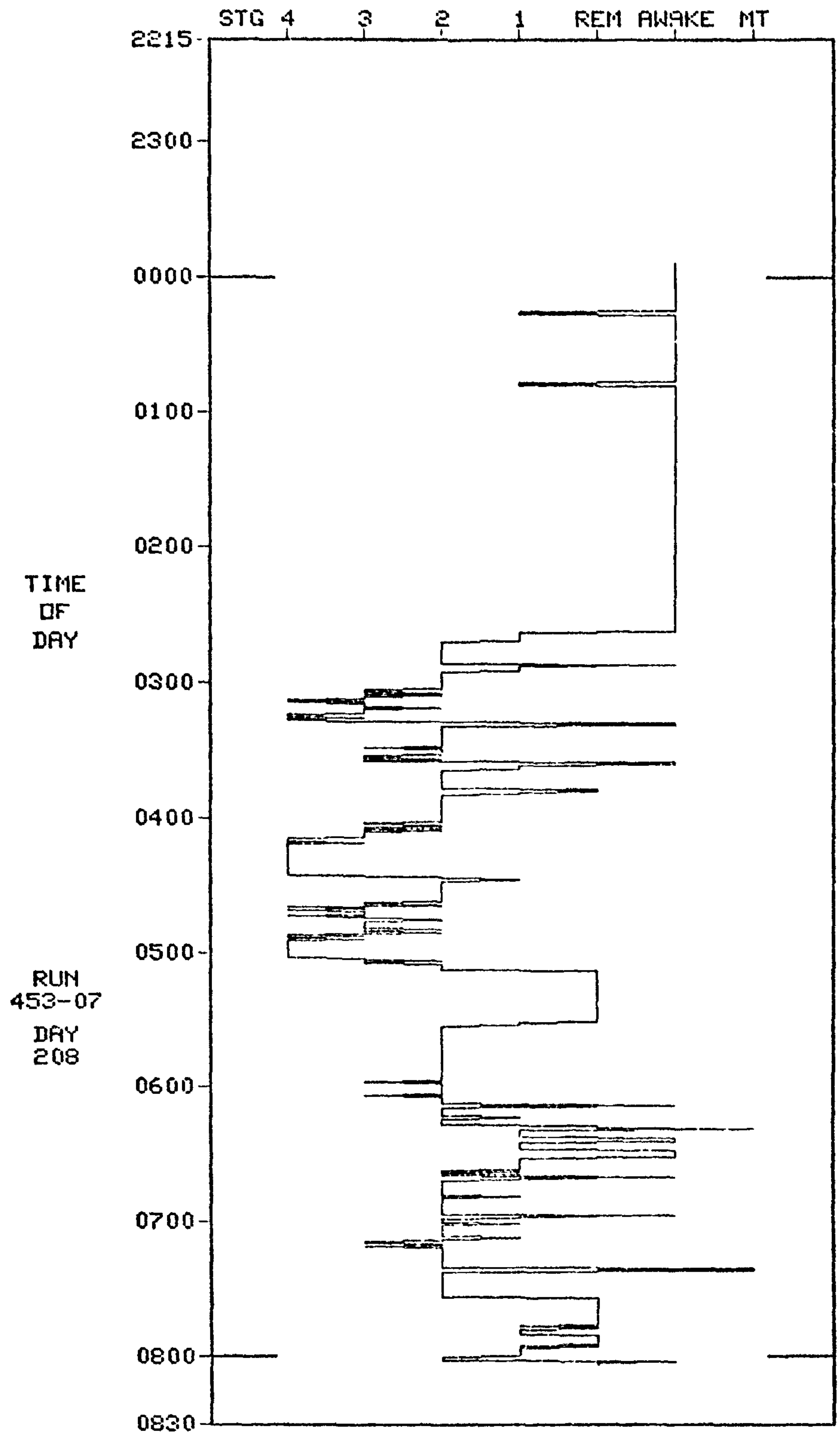

Figure 17. Sleep print from Subject 46 in Low, 60 kt, SS4 (Run 453).

In general, these limited results indicate that the subjects slept as well in the moving as in the static environment if they did not become motion sick. Sickness did interfere with the sleep of some subjects. Indeed, it was surprising to note that at least two individuals were apparently awakened by symptoms which developed during sleep. These observations imply that persons who succumb to motion sickness in the SES environment may be further afflicted with the inability to sleep.

The apparent development of motion sickness among sleeping subjects raises questions regarding the interaction of basic sleep and motion mechanisms within the brain. The labyrinthine sensation of motion is transmitted to the cortex via the vestibular nuclei. The vestibular nuclei are also essential for the inhibition of sensory and motor functions during sleep. These two activities of the vestibular nuclei are mutually antagonistic, and usually the sensation of motion is blocked by the sleep process, once initiated. That the opposite occurred is another indication of the severity of the motion.

Further Assessment of Sleep: Sleepiness Ratings

Rationale and approach. Subjective ratings obtained in response to the Stanford Sleepiness Scale (SSS, Hoddes, Zarcone, & Dement, 1972) have been found sensitive to the effects of sleep loss and related to performance in tests of deductive reasoning (mental arithmetic) and auditory vigilance (Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973; Wilkinson, 1968). Therefore, the SSS was repeatedly administered to the subjects during the long missions as a means of making quantified, subjective comparisons of sleepiness between the static and motion conditions, and the day-sleeper and night-sleeper wake/sleep schedules. The comparisons should substantiate findings arising from the primary (EEG) sleep assessment, with regard to the effects of those conditions and schedules.

Procedure. The SSS is comprised of the following ordered response categories:

1. *Feeling active and vital; alert; wide awake.*
2. *Functioning at a high level, but not at peak; able to concentrate.*
3. *Relaxed; awake, not at a full alertness; responsive.*
4. *A little foggy, not at peak; let down.*
5. *Fogginess; beginning to lose interest in remaining awake; slowed down.*
6. *Sleepiness; prefer to be lying down; fighting sleep, woozy.*
7. *Almost in reverie; sleep onset soon; lost struggle to remain awake.*

Each subject in both moving and static cabins was asked to refer to that scale, and indicate his condition to the Test Administrator at approximately 4-hour intervals, beginning at 1200 hours, except during sleep periods.

Results and discussion. The analysis of SSS scores was restricted to data collected from only 12 subjects (5 night-sleepers, 7 day-sleepers) who were able to complete at least one 24- to 48-hour exposure to any motion condition, and at least one 48-hour static condition. Data from the other subjects could not be included due to their lack of completeness. Because the type of motion exposure varied from subject to subject no differential assessment of motion or SSS scores was attempted. Rather, each subject's SSS scores were averaged by sampling times across all of his motion exposures, and compared to his average SSS scores for the corresponding static times. This comparison permitted only a relatively crude evaluation of the general effects of SES motion on sleepiness ratings. A listing of the subjects and conditions which provided data for this analysis is given in Appendix K.

Individual SSS averages were grouped and averaged to yield time-of-day curves by schedule and condition. The results are shown in Figure 18. These indicate that the subjects on both wake/sleep schedules showed trends of increasing sleepiness during their awake periods, and that sleep relieved those feelings of sleepiness. The five night-sleepers were least sleepy 4 hours after arising (1200 hours), whereas the seven day-sleepers were least sleepy at their time of arising (2000 hours). Both groups reached maximum levels of sleepiness just prior to retiring.

Differences in mean SSS scores between schedules and conditions were evaluated for statistical significance using a three-factor analysis of variance: work/sleep schedule, static versus motion, and time of day. The time-of-day effect was significant ($F = 10.94$; $df = 4, 40$; $p < .01$), however, there was no general effect of motion ($F = .03$; $df = 1, 10$), or of sleep schedule ($F = .04$; $df = 1, 10$).

The lack of a significant difference between SSS ratings obtained from day- and night-sleepers indicates that both

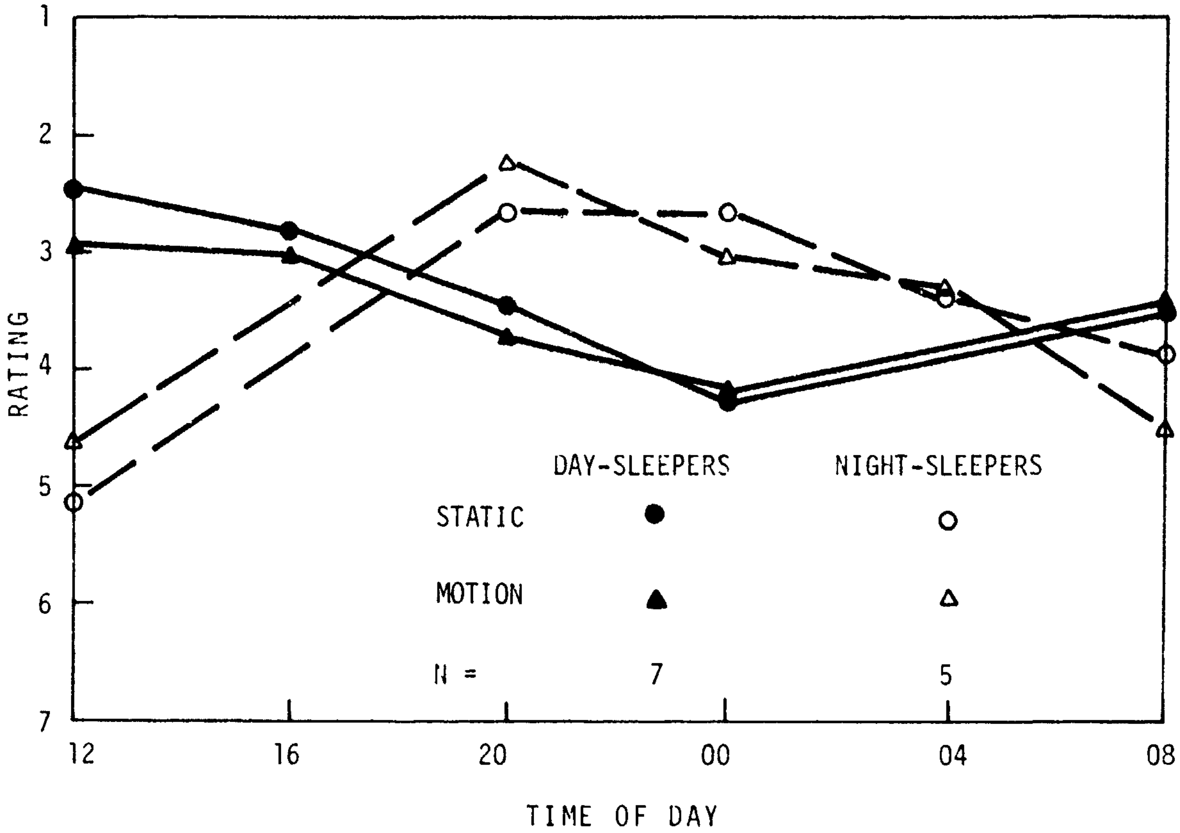

Figure 18. Mean sleepiness ratings of day- and night-sleepers as a function of time of day in the static condition and a sample of motion conditions.

groups were equally acclimatized to their respective wake/ sleep cycles. The lack of any general motion effect may be interpreted as showing that sleepiness was no greater in the subjects during the motion exposures than in the static environment. However, this finding must be interpreted cautiously due to the fact that the results were disproportionately weighted by the results obtained in the 80 kt, SS3 conditions. Certainly, the possibility exists that an unbiased subject sample might have reported greater sleepiness in the more severe motion conditions, if their sleep was disturbed by effects of motion. Evidence of sleep disturbance was found for some subjects in the electrophysiological analysis of sleep described in the preceding section. For that reason, the results of the SSS-rating analysis should be taken to indicate only that 24- to 48-hour exposures to the least severe motion conditions did not seem to produce unusual sleepiness in these subjects.

Assessment of Circadian Rhythmicity: Oral Temperature

Rationale and approach. The circadian[4] periodicity of body temperature is well-known. Its phasing with respect to the clock is determined by the individual's wake/sleep cycle (Kleitman, 1963; Mills, 1973). The range of this cycle, measured orally, is approximately 97°-99°F (36.1°-37.2°C). The nadir of the cycle normally occurs during the early morning hours, while its zenith is reached during the afternoon or evening. The phase relationship of the temperature cycle to the normal day/night, wake/sleep cycle is relatively stable, changing at the rate of about 2 hours per day when the wake/sleep cycle is step shifted. During a chronic inversion of the wake/sleep cycle, the body temperature cycle slowly becomes inverted but generally reduced in amplitude, resulting in lower values reached at the new zenith. Because body temperature and sleep cycle are directly related, it was felt that the identification of disturbances in body temperature cycles, due to inversion of the wake/sleep cycle (for day-sleepers) or due to motion, might aid in the assessment of sleep adequacy.

Apparatus. A digitally indicating, Wheatstone bridge thermistor circuit (Digitec Mod. No. 500-1) was placed upon the Test Administrator's console to serve as the oral/ambient temperature indicator. Appropriate thermistor probes were placed in the moving and static cabins. Leads extending from the probes to the indicator were of such length and resistivity that the error added to the system was less than .18°F (.1°C). The system was thus accurate to ±.33°F (.18°C).

The temperature measuring system was calibrated *in situ* against clinical thermometers in both a controlled-temperature water bath, and orally in eight staff volunteers. It was concluded that the mean error of the thermistor probe in the static cabin was -1.0°F (-.56°C), and of the thermistor probe

[4] Cyclic change with a period of approximately 24 hours.

in the moving cabin, -.2°F (-.11°C), in the oral temperature range. Oral temperature values recorded from the subjects in this experiment were corrected appropriately before analysis.

Procedures. Oral temperatures were measured for each subject in both moving and static cabins at approximately 4-hour intervals, beginning at 1200 hours, except during sleep periods.

Results and discussion. For the reasons described in the preceding section, the analysis of oral temperature was restricted to those subjects who were able to complete at least one 24- to 48-hour exposure to any motion condition. The subjects and conditions of measurement were as described previously for SSS ratings (Appendix K).

All individual oral temperatures were averaged for each time of day by subjects, schedules, and conditions (combined motion versus static), and corrected for thermistor bias.

Individual oral temperature averages were grouped and averaged to give time-of-day curves by schedule and condition. Schedule means were not different within conditions, but the circadian cycles of oral temperature for the day- and night-sleepers were, as expected, 180° (12 hours) out of phase. Since the schedule effect upon oral temperature was only the expected inversion of the oral temperature cycle, day-sleeper data points were lagged 12 hours so that they could be grouped with corresponding night-sleeper data. Finally, combined curves were generated for both the motion and static conditions, extending from the beginning of the sleep period, through the day, to the end of the work period (Figure 19). A three-factor analysis of variance (schedules, conditions, and time of day) performed on the data comprising this figure revealed only one significant difference, overall mean oral temperature was significantly higher in the combined motion conditions than in the static condition (98.34°F versus 97.55°F: $F = 50.13$; $df = 1, 10$; $p < .01$).

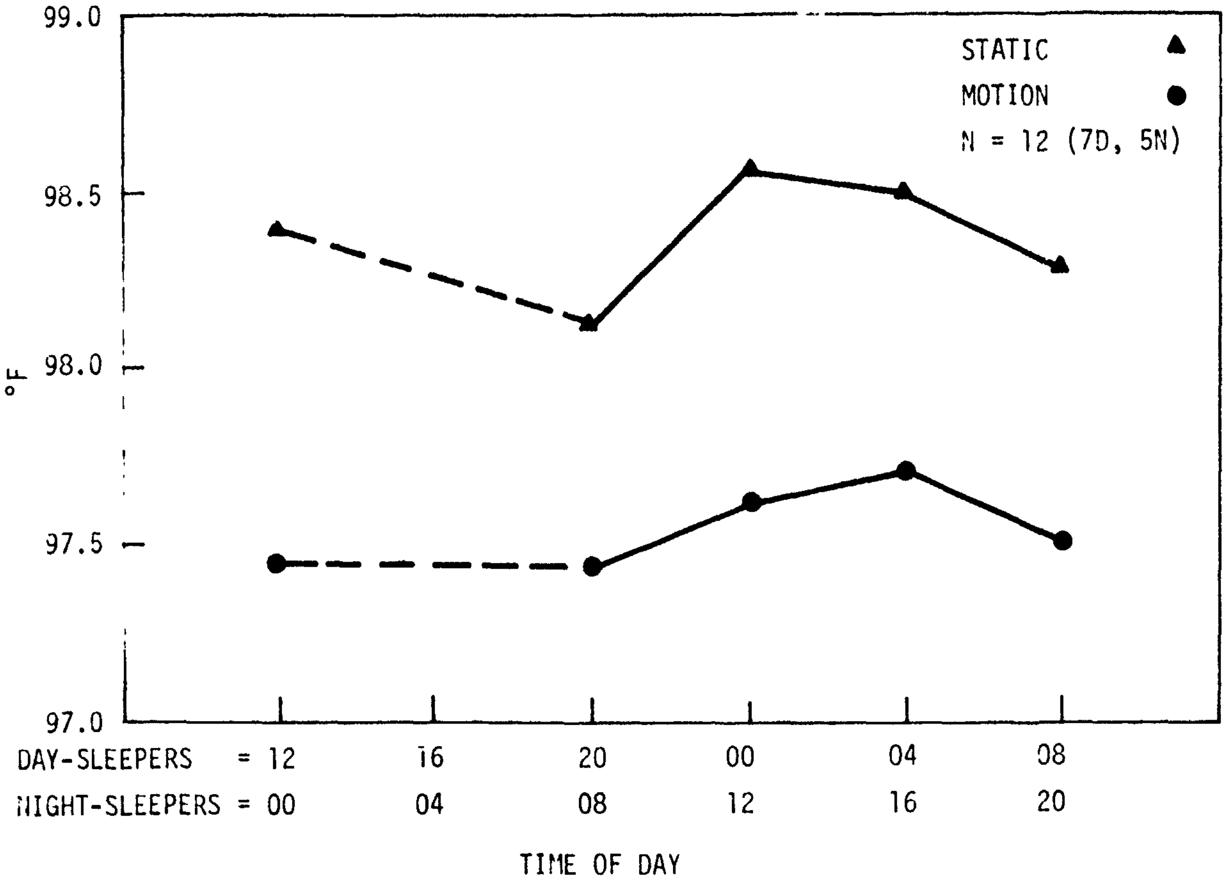

Figure 19. Mean oral temperature for combined night- and day-sleepers as a function of time of day in static conditions and a sample of motion conditions.

The demonstration of expected circadian variations of oral temperature in both night- and day-sleepers indicated that both groups were relatively well adapted to their work/rest schedules. The similar, normal, mean oral temperatures in the two groups indicated no adverse metabolic effect of the inverted work/rest schedule upon the day-sleepers.

Similarly, motion had no effect upon circadian variations of body temperature as compared to the static condition. The maintenance of a higher mean body temperature in the moving environment, however, suggests altered levels of metabolic heat production or altered mechanisms of heat conservation. Mean cabin temperature (regulated by the subjects themselves) apparently had no effect upon this situation. Although the moving cabin was "statistically" warmer than the static cabin, the difference would not be expected to evoke measurable changes in body temperature (Table 6).

TABLE 6

RANGES AND MEAN VALUES
OF CABIN AMBIENT TEMPERATURES

CABIN	RANGE (°F)	MEAN (°F)	SD (°F)
Static	62.7-84.7	73.5	6.5
Moving	66.9-87.7	76.3	4.4

Greater metabolic heat production in the moving environment may have been due to greater compensatory muscular activity. This would support some subjects' reports of physical weariness following motion exposures. The amplitude of the oral temperature elevation, however, was quite small, indicating that such increased muscular effort would be easily tolerable.

If this finding can be substantiated by further research, it would indicate that the eventual SES crew members' diet must have an allowance for an elevated metabolic rate to ensure proper nutrition without weight loss.

ASSESSMENT OF STRESS

Catecholamine Excretion

Rationale and approach. It is common practice to infer the experience of whole-body stress from urinary excretion rates of the catecholamine hormones, adrenaline and noradrenaline. The former is released into the circulation from the adrenal medulla in response to neural impulses from the brain. The latter originates mainly from terminals of nerve fibers comprising the peripheral sympathetic nervous system. Together, the two hormones prepare the body to meet the threat posed by numerous stressors to its homeostatic balance. Many physiological reactions to the catecholamines are well-known and have been aptly summarized by Tepperman (1962, pp. 136-7):

> The over-all response to the effects of simultaneous sympathetic discharge and adrenomedullary secretion involves cardiocirculatory responses which are qualitatively similar to those seen at the beginning of exercise--an increase in cardiac output, increase in pulse rate, rise in blood pressure. In addition, after a brief initial period of apnea, there is an increased minute volume of respiration. Splanchnic vascular constriction (including a reduction in renal blood flow) and dilation of the skeletal muscle vessels produce a redistribution of the enlarged cardiac output which anticipates muscle work. The central nervous system arousal effect of the catecholamine substances results in alertness and quick responsiveness. Hepatic glycogenolysis, its attendant hyperglycemia, and the mobilization from the fat depots of a large supply of free fatty acids (FFA), all collaborate to provide a quick charge of readily available energy to muscles that may be called on. Chemical changes in the muscles themselves increase their capacity for work and possibly diminish the generation of a fatigue signal by the muscle. The central nervous system effects of the substances may, at the same time, diminish central perception of fatigue. As if in anticipation of blood loss, the spleen contracts and adds volume and red cells to the circulation while the coagulability of the blood increases. If a committee of expert physiologists were appointed to draw up specifications for a set of physiological responses that would meet emergency needs it would

> be difficult for them to devise a more interesting or effective set than that described here.

Almost any physical or psychological stressor can, if intense enough, elevate circulating catecholamines and their urinary excretion rates. Included among demonstrated effective agents are pain or injury; cold; heat; sustained high acceleration or vibration; noise; exercise; low or high oxygen pressure; high carbon dioxide pressure; food or water deprivation; immobilization or confinement; and many drugs including alcohol, nicotine, and caffeine (see O'Hanlon, 1970). Emotional stress, or even the demands of a difficult "mental" task, can similarly raise catecholamine levels in blood and urine (O'Hanlon, 1970).

In view of this, the approach taken in the present investigation to estimate the subjects' experience of stress, due to motion or other factors, involved the assay of their total urine output to determine adrenaline and noradrenaline excretion rates in all motion and static conditions.

Apparatus and procedure. Nalgene urine collection bottles were supplied as needed to subjects in both the moving and static cabins. These were prepared beforehand by the addition of sodium metabisulfite (about .5 g) and, after use, by acidification with hydrochloric acid to about .4 N, for preventing catecholamine oxidation. Aliquots (20 ml per sample) were withdrawn and stored frozen at -15°C for later analysis according to the fluorometric method of O'Hanlon, Campuzano, and Horvath (1970).

Subjects were required to empty their bladders immediately before entering the cabin environments. Thereafter, they were required to urinate into individually identified collection bottles. During each subject's waking period he used one bottle, or set of bottles, labeled "wake." He added his final urine to the "wake" bottle immediately prior to retiring for sleep in the bunk. Immediately upon arising from the bunk he was required to urinate in another bottle, labeled "sleep." (If he had to urinate at any time during the sleep period, he also used the latter bottle.) Correspondingly, each subject yielded one waking and one sleeping sample for each 24-hour period during the longer (48-hour) runs. A 6-hour waking sample was also collected from each subject during the shorter runs. In the event that the subject was unable to complete the scheduled run, due to motion sickness or equipment failure, he merely added whatever urine he could void to the collection bottle he was currently using. The shortened collection time was then noted and suitable adjustments were made in calculating the final catecholamine excretion rates.

Results and discussion. Measures of adrenaline and noradrenaline excretion rates ($\dot{A}$ and $\dot{NA}$, respectively) were by far the most complete data obtained from this study. Nearly all scheduled waking and sleeping samples were obtained in every condition, including those from subjects experiencing motion sickness during the sampling period (a full description of the long-mission data is provided in Appendix L).

Data collected during the long-mission static condition were evaluated, first, to determine whether mere confinement was sufficiently stressful to elevate $\dot{A}$ and $\dot{NA}$. A summary of those data are shown in Figure 20.

There is little evidence in Figure 20 that the repeated or prolonged confinement was an unduly stressful experience for the subjects. Mean catecholamine excretion rates did not generally increase with repeated runs in the static environment, and mean rates during the second day of confinement were generally no higher than on the first.[5]

Because the subjects as a group showed little change in $\dot{A}$ or $\dot{NA}$ over repeated static runs, measures of each were

[5] The rise in mean catecholamine excretion rates during the final sleep period of the third static session was entirely attributable to one subject (No. 39)--see Appendix L.

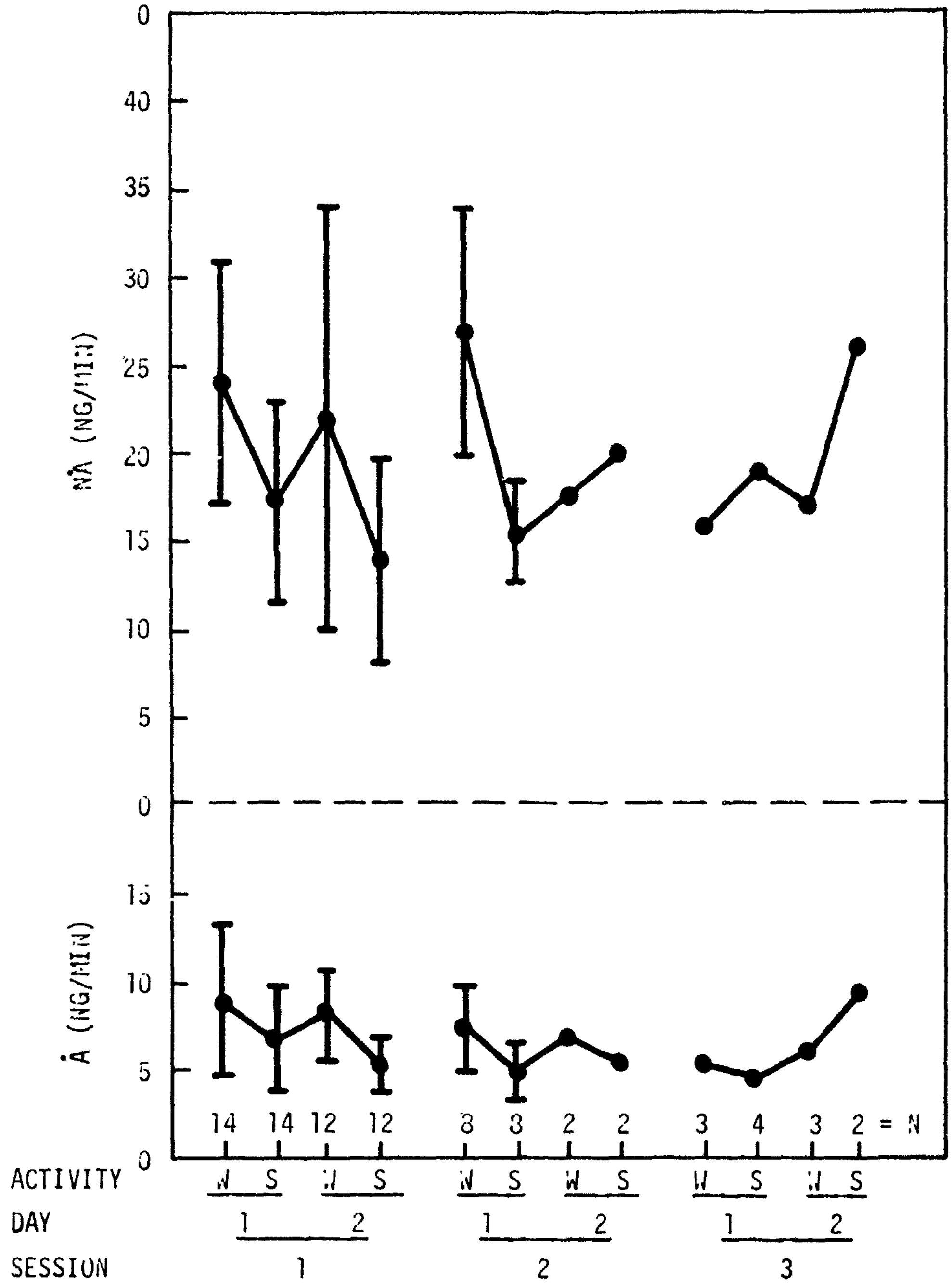

Figure 20. Mean (±SD, where N > 4) for Å and NÅ during waking (W) and sleeping (S), on Days 1 and 2, of successive runs in the static condition.

averaged by subject, activity (wake or sleep), and days within runs to provide respective baseline control values. Measures of $\dot{A}$ and $N\dot{A}$ obtained from the subjects in various motion conditions were then compared to respective average static levels to yield difference scores. The latter are plotted for all subjects in all motion conditions in Figure 21 for $\dot{A}$, and Figure 22 for $N\dot{A}$.

$\dot{A}$ was little affected by motion in all variations of 80 kt, SS3. However, in more severe conditions, $\dot{A}$ was generally elevated with respect to static levels. The mean change in $\dot{A}$ from static to motion was found significant by *t*-test for Medium, 60 kt, SS4 ($t = 3.39$, $df = 7$, $p < .01$); and approached significance for all other short-mission conditions (i.e., t = 3.05, 2.56, 3.01; df = 3, 5, 3; $p < .10$ for Full, 60 kt, SS4, and Medium and Full, 40 kt, SS5, respectively). The failure to measure generally elevated $\dot{A}$ levels during the long-mission, Full, 40 kt, SS5 condition was almost certainly due to the fact that it was undertaken by the most motion-tolerant subjects.

It is also interesting to note that the occurrence of motion sickness was associated with elevated levels of $\dot{A}$ in 10 of 12 cases. Application of the binomial, or "sign," test revealed that the association between $\dot{A}$ elevation and motion sickness was significant ($p = .038$).

Figure 22 shows that mean difference in $N\dot{A}$ varied from condition to condition in a similar though less exaggerated manner than for $\dot{A}$. However, no change in $N\dot{A}$ was found to be significant. Likewise, no significant association was found between elevation of $N\dot{A}$ and the occurrence of motion sickness.

A final descriptive analysis was performed using the absolute values of $\dot{A}$ and $N\dot{A}$ measured in different motion conditions. Although the individual data were variable, the previous analysis had indicated a relationship between mean catecholamine excretion rates and some motion parameter. Particularly, $\dot{A}$ had been shown to rise from the Full, 80 kt,

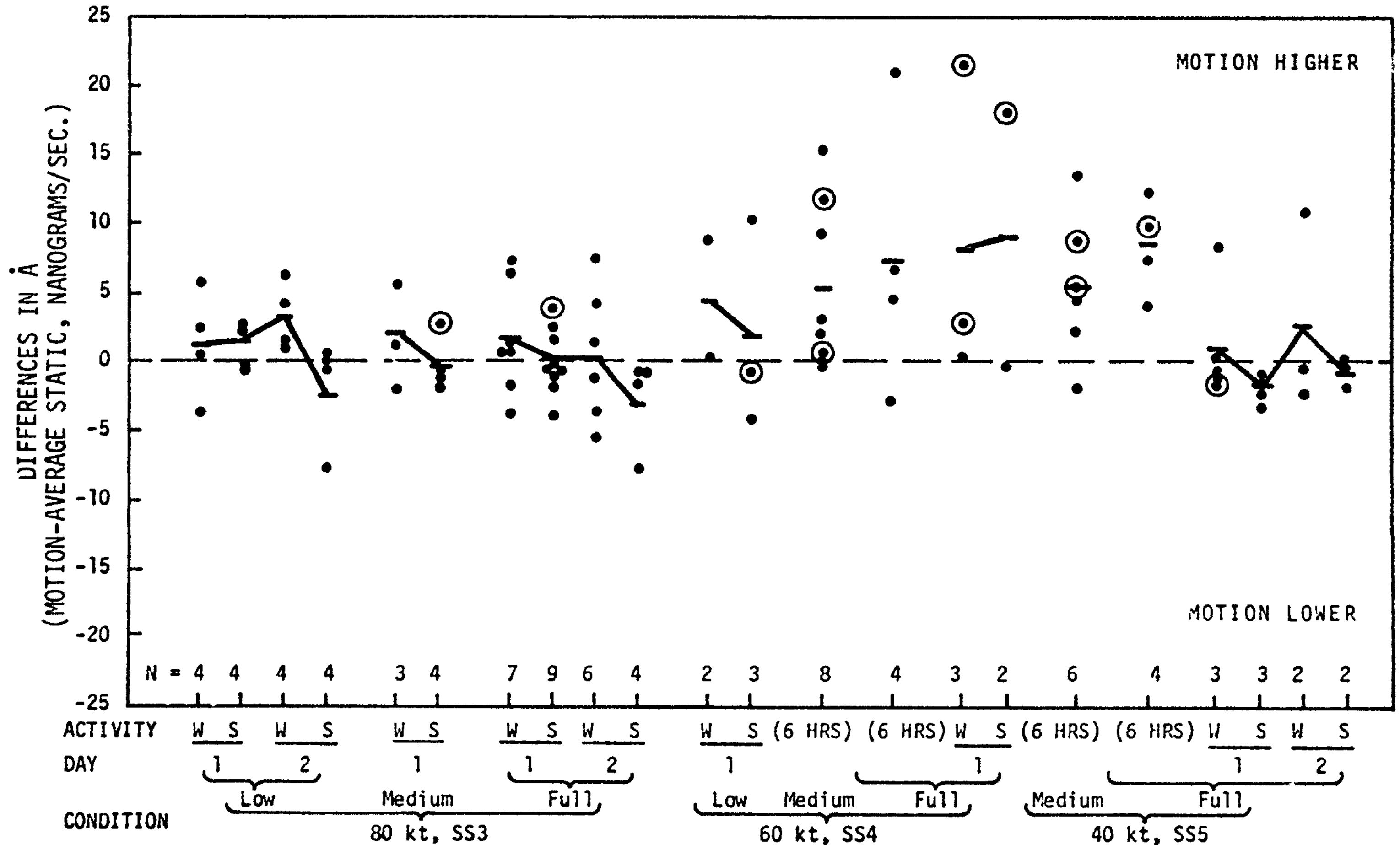

Figure 21. Differences in Å between average static and motion conditions for all possible individual comparisons. (Circled points indicate the subject was motion sick during the corresponding motion period. Horizontal bars indicate mean changes.)

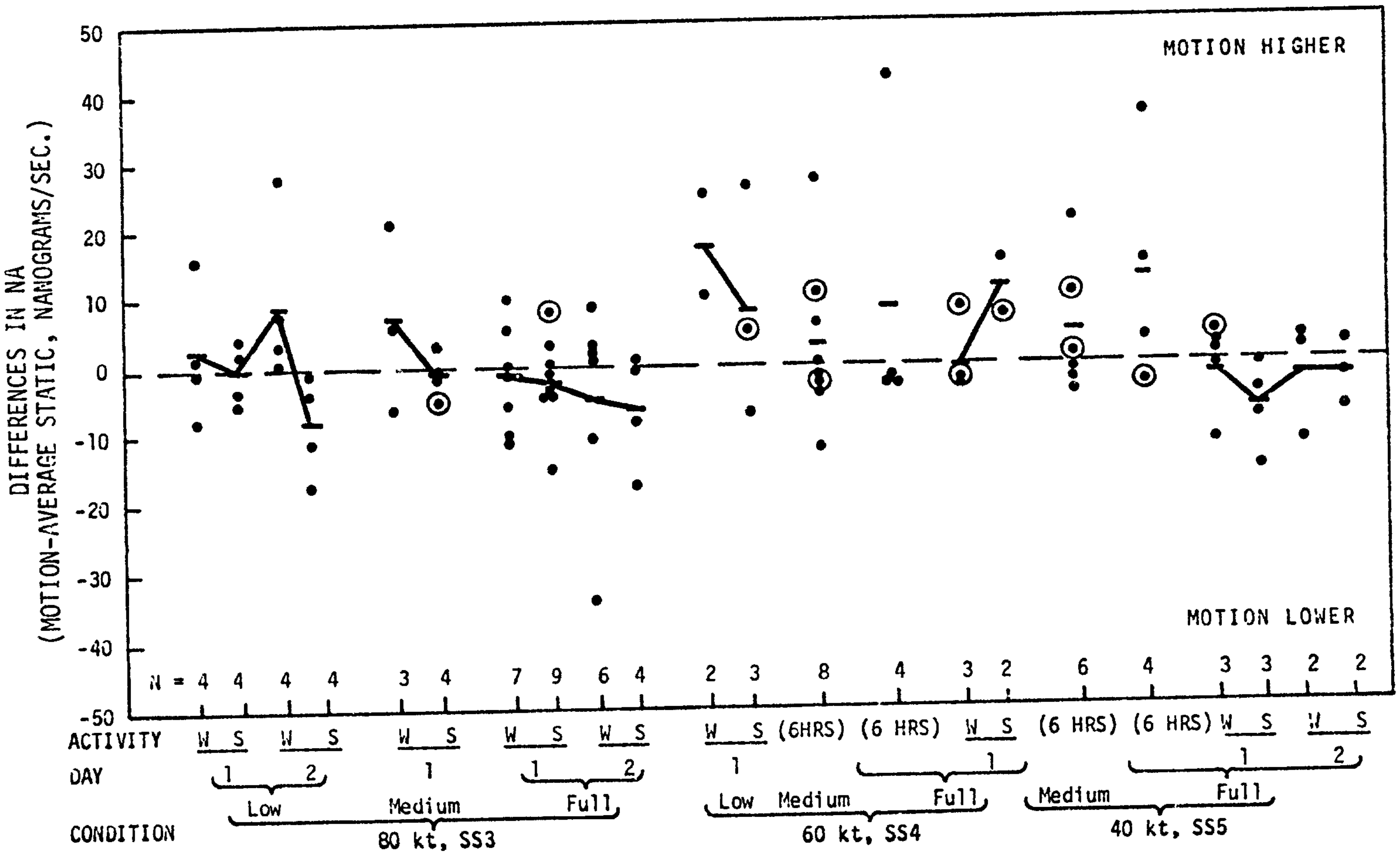

Figure 22. Differences in $\dot{N}A$ between average static and motion conditions for all possible individual comparisons. (Circled points indicate subject was motion sick during corresponding motion period. Horizontal bars indicate mean changes.)

SS3 condition to Medium 60 kt, SS4 and 40 kt, SS5 conditions. The overall rms acceleration imparted in these three conditions was approximately the same, but the spectral distribution of acceleration was markedly different.[6] Both of the higher sea state conditions imparted more energy in the frequency region associated with maximum motion sickness sensitivity, i.e., .1 to .5 Hz (O'Hanlon & McCauley, 1973). To determine whether the experience of stress was more closely related to acceleration within that critical band than to overall acceleration, the mean excretion rates for $\dot{A}$ and $\dot{NA}$, measured during short missions or during the first waking period in long missions, were calculated across subjects and by conditions. These were plotted as a function of the rms heave acceleration imparted by respective motions within the frequency band, .1 to .5 Hz, as shown in Figure 23.

The results in Figure 23 show striking progressive increases in mean excretion rates for both catecholamines with increasing acceleration. Relative to the average waking static level for all subjects, mean $\dot{NA}$ rose by about 35%, and mean $\dot{A}$ by about 45% over the various motion conditions experienced by subgroups.

To further illustrate this motion effect, individual total catecholamine excretion rates were averaged and plotted as a function of rms heave acceleration within the same frequency band (Figure 24). Again, the data were comprised of waking, short-mission, and first-day, long-mission measurements. The results showed a generally increasing trend in mean catecholamine excretion rate with increasing acceleration. Mean levels measured in the variation of 80 kt, SS3 approximated the average static level. However, acceleration greater than about .10 rms g acceleration was associated with progressively higher mean excretion rates. These reached a

[6] See Volume 2 (Facilities, Test Conditions, and Schedules) for a complete description of the respective motion power spectra.

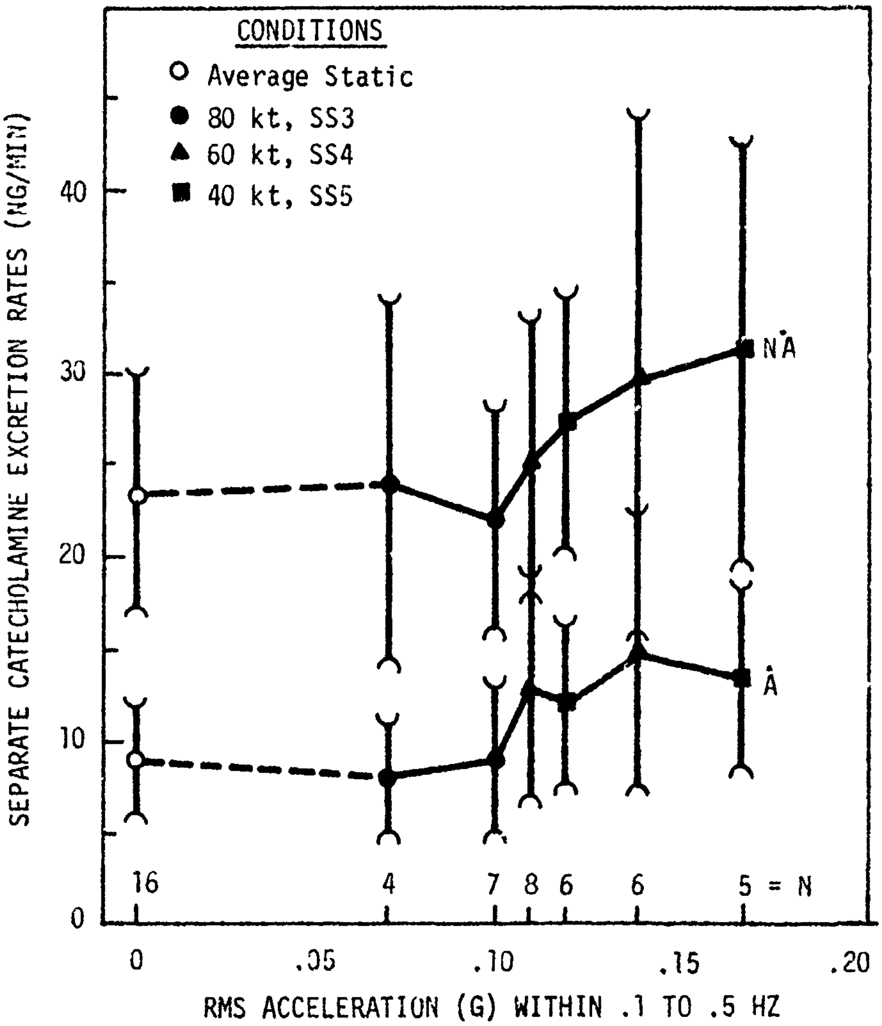

Figure 23. Å and NÅ (M±SD) as separate functions of rms acceleration within the .1 to .5 Hz frequency band for various conditions of motion.

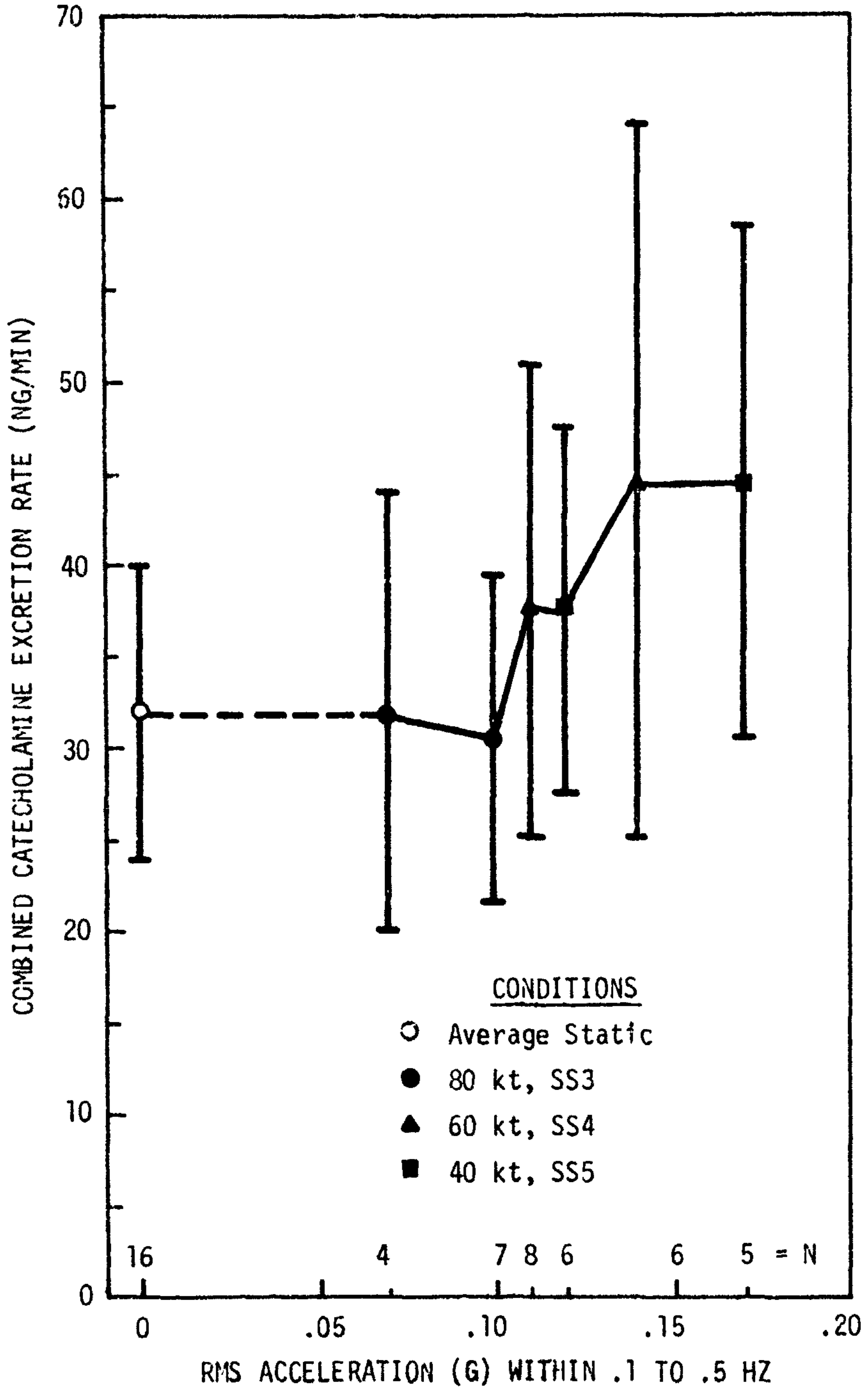

Figure 24. Total catecholamine excretion rate (M±SD) as a function of rms acceleration within the .1 to .5 Hz frequency band for various conditions of motion.

maximum level in the most severe motion conditions which was about 38% above the average static level.

The results of the catecholamine analyses are interesting in several respects. Catecholamine excretion rates, and particularly $\dot{A}$, seem to provide a highly sensitive indication of the relative degree of whole-body stress in individuals exposed to SES-like motion. The systematic rise in catecholamine excretion rates with acceleration imparted within the motion sickness frequency region was demonstrated here for the first time. This demonstration cannot be considered conclusive, however, due to the relatively small number of observations and the biasing of the subject sample toward increasing motion tolerance in the more severe motion conditions. Yet recognizing the sampling bias, it can be logically supposed that the relationship between catecholamine excretion rate and heave acceleration would be even more evident for larger, unbiased samples exposed to the same motions. If confirmed by subsequent research, the results indicate that catecholamine excretion rates may be used for objectively assessing the relative stress produced in individuals exposed to a wide range of SES motion.

A further practical implication of the results is that 24 to 48 hours of exposure to SES motion, which imparts less than .10 rms g heave acceleration within the motion sickness frequency region and less than about .19 g overall, produces no generalized stress response. Judging from the higher mean levels measured in more severe motion conditions, and occasional very high individual levels,[7] more intense motion is definitely stressful, at least for unadapted individuals. The implications

[7] As the most extreme example, Subject 60's $\dot{A}$ and $\dot{NA}$ levels were 25.9 and 53.9 ng/min, respectively, in his short-mission exposure to Full, 60 kt, SS4, whereas his comparable average static levels were 7.9 and 22.4 ng/min. Elevations of such magnitude are generally considered as evidence of substantial stress, which, if repeated or prolonged, might lead to pathological consequences.

are that operational SES motion should be limited to below the level of the Full, 80 kt, SS3 condition studied here; that motion-tolerant individuals should be selected as SES crew members; or, assuming adaptation reduces stress, that crew members should be adapted to the expected motion before duty on the SES.

SUMMARY AND CONCLUSIONS

General Scope

As part (Phase II) of a continuing program for establishing habitability design criteria for a large-scale surface effect ship (SES), 19 novice U.S. Navy enlisted personnel were exposed to motion for periods of up to 48 hours, in a closed cabin mounted on a three-degree-of-freedom simulator (the ONR/HFR Motion Generator). These subjects were variously exposed to eight conditions of full-amplitude or attenuated SES motion, representative of fully developed starboard bow seas traversed at high speeds (i.e., Sea State 3 at 80 kt, Sea State 4 at 60 kt, and Sea State 5 at 40 kt). The results described here were obtained from 16 of these subjects, who were exposed to one or more motion conditions, and who provided comparable data during confinement in a similar, but static, cabin environment. The results pertain to the subjects' (1) cognitive or visual functions, (2) physiological stress, and (3) sleep. Other aspects of their reactions to motion are described in companion volumes of this series.

The Problem of Motion Sickness

Motion sickness was a factor directly or indirectly affecting data collected in all behavioral tests and physiological measurements. Subjects who suffered from severe motion sickness were often unable or unwilling to undertake tests, and frequently withdrew from the motion environment before the scheduled completion of their run. Once this became evident, more motion-tolerant (with respect to sickness) subjects were selected for exposure to more severe motion conditions. As a consequence, the performance results were recognized as being more representative of well subjects than the entire group. Physiological results were similarly biased, though to a lesser extent, i.e., certain physiological measures could be obtained from subjects who were incapable of performing tasks due to motion sickness.

Summary of Results

Radar monitoring under stimulus underload conditions. This task was designed to test the ability to sustain attention during a prolonged (2-hour) and monotonous radar watch. It consisted of visually searching a sea surveillance radar display to detect the infrequent and aperiodic occurrence of a threatening contact (i.e., a surface-to-surface missile approaching at 1200 kts). Performance at the task was generally unaffected by motion.

Radar monitoring under stimulus overload conditions. This task was designed to test complex temporal and spatial pattern recognition in the context of a 2-hour radar watch for the purpose of collision avoidance. It involved visually searching a sea surveillance radar display, showing simultaneous returns from 18 to 25 ships traveling on different courses at different relative speeds. The subject was required to identify and report the occasional contact on a collision course. Limited results showed no effect of motion on performance at the task.

Cryptographic decoding and encoding. The task involved near-field visual search and character recognition and was primarily intended to measure motivation to perform tedious and exacting clerical work. In this task, the subject proceeded at his own pace to either decode or encode standard messages using a code matrix. Code transcription rate was unaffected by motion, except possibly during the second day of exposure to the most severe condition.

Navigational plotting. The plotting task was the most difficult of the test battery. It required attention, visual pattern recognition, memory, and fine motor control under time pressure. The subject was given sequential auditory information and was required to transform it into a spatial coordinate system by plotting his own-ship's course and the position of reported radar contacts. Motion had little effect upon performance, in general. However, the results suggested that performance deteriorated over days of exposure to motion. Also, the two subjects who attempted to perform while motion sick did so poorly, and they quit before its completion.

Visual acuity. Near-field visual acuity was measured at the beginning and end of each work period by requiring the subject to read a series of wall-mounted excerpts from textual material at a distance of 36 inches. Sections in the series varied systematically with respect to character size, and the section containing the smallest legible character size was used to indicate the threshold visual angle. Average threshold under static conditions was about 4.0 arc minutes visual angle. Threshold increased in all motion conditions. However, the magnitude of the change was generally small, never exceeding .7 arc minutes. Absolute average threshold values in different motion conditions varied between 4.0 and 5.0 arc minutes visual angle (i.e., corresponding to critical element sizes of .8 and 1.0 arc minutes, respectively, for the standard visual acuity target, "E").

Assessment of sleep. Selected electrophysiological recordings were manually scored according to standard procedures. In particular, 21 complete sleep recordings obtained from 11 subjects were analyzed in detail. The results showed that sleep was essentially the same under static and motion conditions for subjects who did not suffer from motion sickness. Three subjects obtained disturbed sleep, then experienced early awakening and concomitant symptoms of motion sickness. This result was surprising and may indicate an unusual characteristic of SES motion. However, one subject who had been sick apparently recovered during sleep. Subject sleepiness ratings, primarily obtained in the various 80 kt, SS3 conditions, showed no difference in recovery after sleep obtained in static and motion conditions. Oral temperatures, again, primarily obtained in the less severe motion conditions, showed normal circadian (diurnal) periodicity, and a slight elevation in metabolic heat production during motion exposures.

Assessment of stress. Catecholamine hormone (adrenaline and noradrenaline) excretion rates were measured by assaying urine samples obtained from every subject in every static and motion condition. These measures are widely accepted indices of whole-body stress. The results indicated that there was no elevation in stress experienced during exposures to all variations of the 80 kt, SS3 condition. Moderate average elevations in stress (and a few large individual elevations) were recorded during exposures to more severe motion conditions. Adrenaline excretion rate was related to the occurrence of severe motion sickness. The two catecholamine excretion rates tended to rise as a function of heave acceleration imparted in the motion sickness frequency range (i.e., .1 to .5 Hz), at least above an rms acceleration level of about .10 g.

Conclusions

1. Higher-order cognitive functions, such as attention, visual pattern recognition, and memory, were not impaired in individuals exposed for periods of up to 48 hours to any of the motion studied, so long as they did not suffer from motion sickness.

2. The motivation and, possibly, the ability to perform routine, prolonged mental work was severely degraded in individuals suffering from motion sickness. The full extent of that degradation could not be determined due to the unwillingness or inability of those individuals to accomplish assigned tasks, or even remain in the moving environment.

3. Near-field visual acuity was slightly impaired by all SES motions employed in this investigation. However, characters subtending greater than about 5.0 arc minutes visual angle (critical element size of about 1.0 arc minutes for standard visual acuity target "E") should be legible from normal reading distances in similar motion environments.

4. The quantity and quality of sleep obtained in motion was impaired for some individuals who apparently developed symptoms of motion sickness during sleep. When sickness did not occur, individuals seemed to sleep normally, at least during variations of the 80 kt, SS3 motion.

5. "Stress" hormone excretion rates were generally elevated during exposures to variations of the 60 kt, SS4 and 40 kt, SS5 conditions. Individual differences were large, indicating widely different tolerances for stressful motion effects. On the average there appeared to be a monotonic relationship between stress and heave acceleration, imparted in the .1 to .5 Hz frequency range.

General Conclusion

The results of Phase II of the surface effect ship habitability simulations can be divided into two categories: data relating to crewmen who became motion sick and data relating to crewmen who did not. For those who became motion sick during one or more of the simulated sea conditions, the typical behavioral syndrome involved lack of motivation or decreased ability to perform the assigned tasks. Those subjects usually aborted their run soon after emesis. For the subjects who did not become sick, the motions did not significantly interfere with simulated shipboard operations. While slight decrements in task performance were occasionally observed in these crewmen, they were never great enough to be considered practically significant.

The different speed/sea state combinations tended to affect the incidence of motion sickness rather than task performance. Most subjects could withstand the 80 kt, SS3 condition without experiencing significant motion sickness symptomatology, whereas the higher sea states tended to induce nausea and vomiting. In addition, there was a slight increase in whole-body stress of the subjects, as evidenced by catecholamine analyses, with increased motion severity.

The subjects for Phase II of this series were U.S. Navy enlisted personnel with little or no previous sea experience, whereas the eventual crew of the operational SES will be experienced seamen. It is extremely difficult to generalize about experienced SES personnel from data obtained from subjects who are unadapted to sea motion. Motion sickness appeared to be the major problem associated with simulated SES motions in this study, but it could be minimized by ship design engineering efforts to reduce the heave acceleration in the frequency ranges associated with motion sickness (i.e., .1 to .5 Hz). If the problem of motion sickness is overcome through adaptation, no serious degradation of task performance would be anticipated on the basis of the present data.

REFERENCES

Hoddes, E., Zarcone, V., & Dement, W. C. Cross-validation of the Stanford Sleepiness Scale. *Sleep Research*, 1972, *1*, 91 (abstract).

Hoddes, E., Zarcone, V., Smythe, H., Phillips, R., & Dement, W. C. Quantification of sleepiness: A new approach. *Psychophysiology*, 1973, *10*, 431-436.

Hornick, R. J. Vibration. In J. F. Parker & V. R. West (Eds.), *Bioastronautics Data Book*. Falls Church, Virginia: BioTechnology, Inc., 1972.

Jex, H. R., O'Hanlon, J. F., & Ewing, C. L. Simulated rough water operations during long cruises in a 2000-ton Surface Effect Ship, Phases I and IA. *Systems Technology, Inc., Tech. Rep. 1057-2*, 1976.

Kleitman, N. *Sleep and Wakefulness*. University of Chicago Press, 1963.

Mills, J. N. *Biological Aspects of Circadian Rhythms*. London: Plenum Press, 1973.

Money, K. E. Motion sickness. *Physiological Reviews*, 1970, *50*, 1-39.

O'Hanlon, J. F. Vigilance, the plasma catecholamines and related biochemical and physiological variables. *Human Factors Research, Inc., Tech. Rep. 787-2*, 1970.

O'Hanlon, J. F., Campuzano, H. C., & Horvath, S. M. A flurometric assay for subnanogram concentrations of adrenaline and noradrenaline in plasma. *Human Factors Research, Inc., Tech. Rep. 787-1*, 1970. (Published in *Analytical Biochemistry*, 1970, *34*, 568-581.)

O'Hanlon, J. F., & McCauley, M. E. Motion sickness incidence as a function of the frequency and acceleration of vertical sinusoidal motion. *Human Factors Research, Inc., Tech. Rep. 1733-1*, 1973. (Published in *Aerospace Medicine*, 1974, *45*(4), 366-369.)

O'Hanlon, J. F., Royal, J. W., & Beatty, J. EEG theta regulation and radar monitoring performance in a controlled field experiment. *Human Factors Research, Inc., Tech. Rep. 1738-F*, 1975.

Reason, J. T., & Brand, J. J. *Motion Sickness*. London: Academic Press, 1975.

Rechtschatten, A., & Kales A. (Eds.). *A Manual of Standardized Terminology, Techniques and Scoring System for Sleep Stages of Human Subjects*. Los Angeles. BIS/BRI, University of California, 1968.

Schmidt, H. S., & Kaelbling, R. The differential laboratory adaptation of sleep parameters. *Biological Psychiatry*, 1971, *3*, 33-45.

Schmidtke, H. *Leistungsbeeinflussende Faktoren im Radar-Beobachtungsdienst*. Forschungsbericht des Landes Nordrhein-Westfalen Nr. 1736. Köln-Opladen: Westdeutscher Verlag, 1965.

Tepperman, J. *Metabolic and Endocrine Physiology*. Chicago: Medical Publishers, 1962.

Wilkinson, R. T. Sleep deprivation: Performance tests for partial and selective sleep deprivation. *Progress in Clinical Psychology*, 1968, *8*, 28-43.

Williams, R. L., Karacan, I., Hursch, C. J. *EEG of Human Sleep*. New York: Wiley, 1974.

APPENDIX A

SUMMARY OF RADAR 1 RESULTS FROM THE STATIC CONDITION:
AVERAGE SWEEPS-TO-DETECT TARGETS IN THE PRETEST, LONG WATCH, AND POSTTEST BY SUBJECTS, RUNS, AND TESTS (DAYS) WITHIN RUNS

			TEST NO. 1 (FIRST DAY)			TEST NO. 2 (SECOND DAY)			MEAN TESTS 1 AND 2		
SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	STATIC RUN SEQUENCE	PRETEST	LONG WATCH	POSTTEST	PRETEST	LONG WATCH	POSTTEST	PRETEST	LONG WATCH	POSTTEST
50	N	1	3.2	4.4	2.7	2.8	5.5	2.3	3.0	4.95	2.5
		2	3.3	6.2	9.8	6.0	6.7	7.8	4.65	6.45	6.9
		3	4.8	7.6	8.0	3.0	8.2	5.3	3.9	7.9	6.65
		Average =	3.8	6.1	6.8	3.9	6.8	5.1	3.85	6.4	5.35
43	D	1	3.7	4.2	5.0	7.7	4.1	4.0	5.7	4.15	4.5
		2	3.0	6.7	9.0	5.7	7.6	10.5	4.35	7.15	9.75
		3	6.2	6.7	8.3	(	T	)	--	--	--
		Average =	4.3	5.9	7.4	13.4	6.7	7.25	5.0	5.65	7.1
48	N	1	8.3	8.6	9.3	(	T	)	--	--	--
		2	8.2	10.4	8.0	(	S	)	--	--	--
		Average =	8.25	9.5	8.65	--	--	--	--	--	--

SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	STATIC RUN SEQUENCE	TEST NO. 1 (FIRST DAY) PRETEST	LONG WATCH	POSTTEST	TEST NO. 2 (SECOND DAY) PRETEST	LONG WATCH	POSTTEST	MEAN TESTS 1 AND 2 PRETEST	LONG WATCH	POSTTEST
39	D	1	6.5	4.2	3.3	7.2	7.3	5.3	6.85	5.75	4.3
		2	8.4	7.1	6.3	(	S	)	--	--	--
		3	7.3	8.9	9.8	6.7	9.6	9.3	7.0	9.25	9.55
		Average =	7.4	6.7	6.5	6.95	8.45	7.3	6.9	7.5	6.9
44	N	1	5.0	5.6	6.75	2.7	3.9	3.8	3.85	4.75	5.3
		2	4.5	5.9	(T)	(	S	)	--	--	--
		Average =	4.75	5.75	6.75	--	--	--	--	--	--
49	D	1	2.6	5.3	2.5	3.2	3.8	2.3	2.9	4.6	2.4
		2	2.0	3.7	2.7	(	S	)	--	--	--
		3	3.3	3.6	(T)	(	S	)	--	--	--
		Average =	2.6	4.2	2.6	--	--	--	--	--	--
52	N	1	5.7	6.9	3.4	6.3	7.75	5.75	6.0	7.3	4.8
		2	5.7	7.4	8.3	(	S	)	--	--	--
		Average =	5.7	7.2	5.9	--	--	--	--	--	--

SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	STATIC RUN SEQUENCE	TEST NO. 1 (FIRST DAY)			TEST NO. 2 (SECOND DAY)			MEAN TESTS 1 AND 2		
			PRETEST	LONG WATCH	POSTTEST	PRETEST	LONG WATCH	POSTTEST	PRETEST	LONG WATCH	POSTTEST
47	D	1	5.2	3.8	2.3	--	--	--	--	--	--
		2	5.2	4.6	4.5	--	--	--	--	--	--
		Average =	5.2	4.2	3.4	--	--	--	--	--	--
38	D	1	2.0	4.2	1.7	(	S	)	--	--	--
35	D	1	8.3	7.4	6.3	(	S	)	--	--	--
51	D	1	8.3	9.9	9.0	9.5	9.4	7.5	8.9	9.7	8.25
40	N	1	9.0	9.8	10.0	8.7	6.8	5.2	8.85	9.25	7.6
60	D	1	3.2	3.3	3.3	6.0	5.8	6.2	4.6	4.6	4.8
61	N	1	2.7	3.7	(T)	4.5	4.6	4.4	3.6	4.2	--

SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	STATIC RUN SEQUENCE	TEST NO. 1 (FIRST DAY)			TEST NO. 2 (SECOND DAY)			MEAN TESTS 1 AND 2		
			PRETEST	LONG WATCH	POSTTEST	PRETEST	LONG WATCH	POSTTEST	PRETEST	LONG WATCH	POSTTEST
56	D	1	3.0	4.2	2.7	3.5	5.1	3.7	3.25	4.65	2.95

T = Test not administered due to failure of test apparatus.

S = Test not scheduled (i.e., session terminated after 24 hours).

APPENDIX B

SUMMARY OF RADAR 1 RESULTS FROM MOVING CONDITIONS: AVERAGE SWEEPS-TO-DETECT TARGETS IN THE PRETEST, LONG WATCH, AND POSTTEST BY CONDITIONS, SUBJECTS, AND TESTS (DAYS) WITHIN CONDITIONS

CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	TEST NO. 1 (FIRST DAY) PRETEST	TEST NO. 1 (FIRST DAY) LONG WATCH	TEST NO. 1 (FIRST DAY) POSTTEST	TEST NO. 2 (SECOND DAY) PRETEST	TEST NO. 2 (SECOND DAY) LONG WATCH	TEST NO. 2 (SECOND DAY) POSTTEST	MEAN TESTS 1 AND 2 PRETEST	MEAN TESTS 1 AND 2 LONG WATCH	MEAN TESTS 1 AND 2 POSTTEST
Low, 80 kt, SS3	483	50	N	1.7	2.4	2.2	2.8	9.9	4.0	2.25	6.2	3.1
		43	D	2.5	3.5	3.0	2.3	3.4	2.7	2.4	3.45	2.85
	485	48	N	4.2	6.0	6.2	3.7	5.1	7.5	3.95	5.6	6.9
		39	D	4.2	8.1	4.3	2.8	5.6	8.3	3.5	6.9	6.3
	Mean =	N Sleepers		2.95	4.2	4.2	3.25	7.5	5.75	3.1	5.9	5.0
		D Sleepers		3.35	5.8	3.65	2.55	4.5	5.5	2.95	5.2	4.6
		All Subjects		3.15	5.0	3.9	2.9	6.0	5.6	3.0	5.5	4.8
Medium, 80 kt, SS3	424	49	N	(	E	)	(	E	)	--	--	--
		44	D	2.3	3.1	1.8	(	E	)	--	--	--
	439	52	N	5.7	5.3	3.3	(	S	)	--	--	--
		47	D	3.0(I)	4.6(I)	(T)	(	S	)	--	--	--
	440	49	N	2.7	2.4	1.8	(	S	)	--	--	--
		44	D	(	M	)	(	S	)	--	--	--
		38	D	3.3	3.5	2.2	(	S	)	--	--	--

CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	TEST NO. 1 (FIRST DAY)			TEST NO. 2 (SECOND DAY)			MEAN TESTS 1 AND 2		
				PRETEST	LONG WATCH	POSTTEST	PRETEST	LONG WATCH	POSTTEST	PRETEST	LONG WATCH	POSTTEST
Medium, 80 kt, SS3 (Cont'd)	455	46	N	1.5	1.7	2.3	(	S	)	--	--	--
		38	D	(	M	)	(	S	)	--	--	--
	457	49	N	2.6	4.2	1.3	(	S	)	--	--	--
		35	D	4.0	3.7	3.7	(	S	)	--	--	--
Mean =		N Sleepers		3.1	3.4	2.2	--	--	--	--	--	--
		D Sleepers		3.2	3.2	2.6	--	--	--	--	--	--
		All Subjects		3.2	3.6	2.3	--	--	--	--	--	--
Full, 80 kt, SS3	487	43	N	2.2	2.8	2.2	(	E	)	--	--	--
		50	D	2.7	6.3	3.4	(	E	)	--	--	--
	489	39	N	5.3	7.4	11.0	(	T	)	--	--	--
		48	D	(	M	)	(	M	)	--	--	--
		51	D	5.5	6.3	6.2	3.5	8.0	10.9	4.5	7.15	8.55
	525	40	N	3.2	2.9	2.2	2.8	2.9	2.7	3.0	2.9	2.45
		60	D	2.2	2.7	2.3	2.8	3.2	2.8	2.5	2.95	2.55
	527	61	N	1.7	1.8	2.3	1.7	2.3	1.9	1.7	2.05	2.55
		56	D	1.9	3.6	2.3	1.7	3.6	2.7	1.8	3.6	2.5

CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	TEST NO. 1 (FIRST DAY)			TEST NO. 2 (SECOND DAY)			MEAN TESTS 1 AND 2		
				PRETEST	LONG WATCH	POSTTEST	PRETEST	LONG WATCH	POSTTEST	PRETEST	LONG WATCH	POSTTEST
	Mean =		N Sleepers	3.1	3.7	4.4	2.3	2.6	2.3	2.35	2.5	2.5
			D Sleepers	3.1	4.7	3.6	2.7	4.9	5.5	2.9	4.6	4.5
			All Subjects	3.1	4.2	4.0	2.5	4.0	4.2	2.7	3.7	3.7
Low, 60 kt, SS4	453	46	N	1.2	2.3	1.7	(	S	)	--	--	--
		38	D	(	T	)	(	S	)	--	--	--
	454	49	N	1.8	3.6	1.7	(	S	)	--	--	--
		47	D	(	M	)	(	S	)	--	--	--
Mean = Both Subjects				1.6	2.95	1.7	--	--	--	--	--	--
Full, 60 kt, SS4	446	52	N	(T)	6.3	(T)	(	E	)	--	--	--
		47	D	(	E	)	(	E	)	--	--	--
	451	49	N	2.0	2.9	2.0	(	M	)	--	--	--
		47	D	(	M	)	(	M	)	--	--	--
	550	40	N	4.8	3.9	6.8	(	M	)	--	--	--
		60	D	(	M	)	(	M	)	--	--	--
Mean = All Subjects				3.4	4.4	4.4	--	--	--	--	--	--

CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	TEST NO. 1 (FIRST DAY)			TEST NO. 2 (SECOND DAY)			MEAN TESTS 1 AND 2		
				PRETEST	LONG WATCH	POSTTEST	PRETEST	LONG WATCH	POSTTEST	PRETEST	LONG WATCH	POSTTEST
Full, 40 kt, SS5	494	43	N	2.0	3.6	1.8	2.5	3.6	2.5	2.25	3.6	2.15
		50	D	(	M	)	(	M	)	--	--	--
	496	39	N	(	I-M	)	(	S	)	--	--	--
		51	D	5.3	10.6	4.8	(	S	)	--	--	--
	547	51	N	6.2	4.4	(T)	4.2	6.8	6.0	5.2	5.6	--
		43	D	2.7	5.1	7.2	2.3	5.3	3.3	2.5	5.2	2.4
Mean =		N Sleepers		4.1	4.0	1.8	--	--	--	--	--	--
		D Sleepers		4.0	7.85	6.0	--	--	--	--	--	--
		Both Subjects		4.15	5.9	4.6	3.0	5.2	3.9	3.35	4.8	--

Note: Characters within the table indicate the following:

I = Evidence of subject ill (motion sick) during test.
T = Test not administered due to failure of test apparatus.
E = Test not administered due to failure of MOGEN drive system.
M = Subject withdrew from condition due to motion sickness prior to test.

APPENDIX C

SUMMARY OF RADAR 2 RESULTS FROM THE STATIC CONDITION:
AVERAGE PERCENT OF COLLISION COURSE REMAINING AFTER DETECTION
BY SUBJECTS, RUNS, AND TESTS (DAYS) WITHIN RUNS

SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	STATIC RUN SEQUENCE	TEST 1 (FIRST DAY)	TEST 2 (SECOND DAY)	MEAN TESTS 1 AND 2
50	N	1	25.0	41.1	33.1
		2	24.7	22.4	23.6
		3	9.8	36.3	23.1
		MEAN =	19.8	33.3	26.6
43	D	1	59.7	55.2	57.5
		2	66.6	70.0	68.3
		3	61.3	62.7	62.0
		MEAN =	62.5	62.6	62.0
48	N	1	8.6	8.1	8.4
		2	6.1	(S)	--
		MEAN =	7.4	--	--

SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	STATIC RUN SEQUENCE	TEST 1 (FIRST DAY)	TEST 2 (SECOND DAY)	MEAN TESTS 1 AND 2
39	D	1	64.5	50.8	57.7
		2	54.4	(S)	--
		3	73.6	73.2	73.4
			MEAN = 64.17	62.0	65.5
51	D	1	(T)	72.4	--
40	N	1	63.5	71.9	67.7
60	D	1	74.5	75.2	74.9
61	N	1	79.3	87.8	81.1
56	D	1	75.1	59.4	67.3

S = Test not scheduled (i.e., session terminated after 24 hours).

T = Test not administered due to failure of test apparatus.

APPENDIX D

SUMMARY OF RADAR 2 RESULTS FROM MOVING CONDITIONS:
AVERAGE PERCENT OF COLLISION COURSE REMAINING AFTER DETECTION

CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	TEST 1 (FIRST DAY)	TEST 2 (SECOND DAY)	MEAN TESTS 1 AND 2
Low, 80 kt, SS3	483	50	N	38.5	33.0	35.8
		43	D	69.8	74.2	72.0
	485	48	N	13.6	39.2	26.4
		39	D	58.3	61.1	59.7
		Mean =	N Sleepers	26.1	36.1	31.1
			D Sleepers	64.1	67.7	65.9
			All Subjects	45.1	31.9	48.5
Full, 80 kt, SS3	487	43	N	74.0	(E)	--
		50	D	22.9	(E)	--
	489	39	N	50.9	55.9	53.4
		48	D	(M)	(M)	--
		51	D	32.3	65.0	48.7
	525	40	N	79.0	73.2	76.1
		60	D	80.1	82.1	81.1
	527	61	N	74.9	74.1	74.5
		56	D	61.5	47.3	54.4

CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	TEST 1 (FIRST DAY)	TEST 2 (SECOND DAY)	MEAN TESTS 1 AND 2
		Mean =	N Sleepers	70.0	67.7	68.0
			D Sleepers	48.9	64.8	61.4
			All Subjects	59.5	66.3	64.7
Full, 40 kt, SS5	494	43	N	70.5	69.8	70.2
		50	D	(M)	(M)	--
	496	39	N	(M)	(S)	--
		51	D	7.14	(S)	--
	547	51	N	72.3	66.5	69.4
		43	D	75.1	60.5	67.8
		Mean =	N Sleepers	71.4	68.2	69.8
			D Sleepers	73.3		
			All Subjects	72.3	65.6	69.1

Note: Characters within the table indicate the following:

E = Equipment failure.
M = Subject aborts due to motion sickness.
S = Scheduled termination.

APPENDIX E

SUMMARY OF CRYPTOGRAPHY RESULTS (DECODING AND ENCODING) FROM THE STATIC CONDITION: MEAN NUMBER OF CHARACTERS CORRECTLY DECODED OR ENCODED PER MINUTE BY SUBJECTS, RUNS, AND TESTS (DAYS) WITHIN RUNS

SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	STATIC RUN SEQUENCE	TEST 1 (FIRST DAY)		TEST 2 (SECOND DAY)		MEAN TESTS 1 AND 2	
			DECODE	ENCODE	DECODE	ENCODE	DECODE	ENCODE
50	N	1	17.0	11.1	17.5	12.2	17.3	11.7
		2	12.8	9.1	14.5	9.3	13.7	9.2
		3	14.0	14.4	17.1	8.0	15.6	11.2
		Mean =	14.6	11.5	16.4	9.8	15.5	10.7
43	D	1	15.4	11.8	17.3	14.2	16.4	13.0
		2	18.3	16.3	16.9	15.9	17.6	16.1
		3	17.9	16.7	15.9	17.0	16.9	16.9
		4	15.1	12.1	(S	)	--	--
		5	15.0	14.4	(S	)	--	--
		6	19.8	12.5	(S	)	--	--
		Mean =	16.9	16.0	16.7	15.7	17.0	15.3
48	N	1	7.7	9.9	10.4	11.7	9.1	10.8
		2	10.4	12.1	(S	)	--	--
		Mean =	9.1	11.0	--	--	--	--

SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	STATIC RUN SEQUENCE	TEST 1 (FIRST DAY) DECODE	TEST 1 (FIRST DAY) ENCODE	TEST 2 (SECOND DAY) DECODE	TEST 2 (SECOND DAY) ENCODE	MEAN TESTS 1 AND 2 DECODE	MEAN TESTS 1 AND 2 ENCODE
39	D	1	13.6	10.8	14.8	13.1	14.2	12.0
		2	16.0	15.7	(S	)	--	--
		Mean =	14.8	13.3	--	--	--	--
44	N	1	7.2	5.7	8.9	[illegible].1	8.1	6.9
		2	12.2	6.8	(S	)	--	--
		Mean =	9.7	6.3	--	--	--	--
49	D	1	11.8	9.2	10.9	7.4	11.4	8.3
		2	12.6	10.2	(S	)	--	--
		3	11.5	10.5	(S	)	--	--
		Mean =	12.0	10.0	--	--	--	--
52	N	1	8.7	11.5	10.4	(0)	9.6	--
		2	10.3	13.1	(S	)	--	--
		Mean =	9.5	12.3	--	--	--	--

SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	STATIC RUN SEQUENCE	TEST 1 (FIRST DAY)		TEST 2 (SECOND DAY)		MEAN TESTS 1 AND 2	
			DECODE	ENCODE	DECODE	ENCODE	DECODE	ENCODE
57	D	1	14.6	17.6	(S	)	--	--
		2	14.2	16.7	(S	)	--	--
		Mean =	14.4	17.2	--	--	--	--
38	D	1	9.1	(0)	(S	)	--	--
35	D	1	9.4	10.3	(S	)	--	--
51	D	1	10.8	10.2	10.9	12.4	10.9	11.3
		2	11.1	14.0	(S	)	--	--
		3	9.0	13.2	(S	)	--	--
		4	12.6	14.9	(S	)	--	--
		Mean =	10.9	13.1	--	--	--	--
40	N	1	8.6	8.0	9.2	7.9	8.9	8.0
		2	11.0	10.7	(S	)	--	--
		3	11.8	9.6	(S	)	--	--
		4	12.6	12.6	(S	)	--	--
		Mean =	11.0	10.2	--	--	--	--

SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	STATIC RUN SEQUENCE	TEST 1 (FIRST DAY)		TEST 2 (SECOND DAY)		MEAN TESTS 1 AND 2	
			DECODE	ENCODE	DECODE	ENCODE	DECODE	ENCODE
60	D	1	11.0	9.0	9.7	9.8	10.4	9.4
		2	9.6	11.4	(S	)	--	--
		3	12.4	14.2	(S	)	--	--
		4	14.3	15.4	(S	)	--	--
		Mean =	11.8	12.5	--	--	--	--
61	N	1	10.4	10.3	11.3	10.0	10.9	10.2
		2	12.7	11.8	(S	)	--	--
		3	11.8	11.5	(S	)	--	--
		Mean =	11.6	11.2	--	--	--	--
56	D	1	9.4	12.8	10.1	12.3	9.8	12.6
		2	10.7	10.1	(S	)	--	--
		3	10.6	10.8	(S	)	--	--
		4	10.3	15.0	(S	)	--	--
		Mean =	10.3	12.2	--	--	--	--

SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	STATIC RUN SEQUENCE	TEST 1 (FIRST DAY)		TEST 2 (SECOND DAY)		MEAN TESTS 1 AND 2	
			DECODE	ENCODE	DECODE	ENCODE	DECODE	ENCODE
47	D	1	9.4	10.2	9.9	10.6	9.7	10.4
		2	8.8	9.3	(S	)	--	--
		Mean =	9.1	9.8	--	--	--	--
59	N	1	14.0	13.1	13.2	13.6	13.6	13.4

S = Scheduled termination.

0 = Observer error, no time recorded.

APPENDIX F

SUMMARY OF CRYPTOGRAPHY RESULTS (DECODING AND ENCODING) FROM MOVING CONDITIONS:
MEAN NUMBER OF CHARACTERS CORRECTLY DECODED OR ENCODED PER MINUTE
BY SUBJECTS, RUNS, AND TESTS (DAYS) WITHIN RUNS

				TEST 1 (1ST DAY)		TEST 2 (2ND DAY)		MEAN TESTS 1 & 2	
CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	DECODE	ENCODE	DECODE	ENCODE	DECODE	ENCODE
Low, 80 kt, SS3	483	50	N	13.7	9.9	16.8	10.7	15.3	10.3
		43	D	12.4	13.2	16.5	15.0	14.5	14.1
	485	48	N	3.3	11.3	11.0	13.0	9.8	12.2
		39	D	14.1	11.9	16.0	11.7	15.1	11.8
		Mean =	N Sleeper	11.1	10.6	13.9	11.9	12.6	11.3
			D Sleeper	13.3	12.6	16.3	13.3	14.8	12.9
			All Subjects	12.2	11.6	15.1	12.6	13.7	12.1
Med, 80 kt, SS3	424	44	N	(E	)	(E	)	--	--
		49	D	12.7	10.0	(E	)	--	--
	439	52	N	11.9	9.5	(S	)	--	--
		47	D	7.8(I)	(M)	(M	)	--	--
	440	49	N	2.2	12.1	(S	)	--	--
		44	D	(M	)	(M	)	--	--
		38	D	7.8	6.9	(S	)	--	--

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CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	TEST 1 (1ST DAY) DECODE	TEST 1 (1ST DAY) ENCODE	TEST 2 (2ND DAY) DECODE	TEST 2 (2ND DAY) ENCODE	MEAN TESTS 1 & 2 DECODE	MEAN TESTS 1 & 2 ENCODE
Med, 80 kt, SS3 (Cont'd)	455	46	N	13.5	8.0	(M	)	--	--
		38	D	(M	)	(M	)	--	--
	457	49	N	12.6	9.3	(S	)	--	--
		35	D	14.7	13.1	(S	)	--	--
		Mean =	N Sleeper	12.6	9.8	--	--	--	--
			D Sleeper	10.8	10.0	--	--	--	--
			All Subjects	11.7	9.8	--	--	--	--
Full, 80 kt, SS3	487	43	N	16.5	13.4	(E	)	--	--
		50	D	12.6	11.9	(E	)	--	--
	489	39	N	11.8	13.8	14.3	12.7	13.0	13.3
		48	D	(M	)	(M	)	--	--
		51	D	8.2	9.1	10.4	12.4	9.3	10.8
	525	40	N	12.5	9.8	8.9	8.8	10.7	9.3
		60	D	9.9	10.8	10.5	8.4	9.2	9.6
	527	61	N	11.4	9.8	(O	)	--	--
		56	D	9.7	10.5	9.3	13.1	9.5	11.8

CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	TEST 1 (1ST DAY) DECODE	TEST 1 (1ST DAY) ENCODE	TEST 2 (2ND DAY) DECODE	TEST 2 (2ND DAY) ENCODE	MEAN TESTS 1 & 2 DECODE	MEAN TESTS 1 & 2 ENCODE
		Mean =	N Sleeper	13.0	11.7	11.6	10.8	11.9	11.3
			D Sleeper	10.1	10.6	10.1	11.3	9.3	10.7
			All Subjects	11.6	11.1	10.7	11.1	10.4	10.9
Low, 60 kt, SS4	453	46	N	10.0	7.3	(S	)	--	--
		38	D	9.6	8.3	(S	)	--	--
	454	49	N	13.5	11.1	(S	)	--	--
		47	D	(M	)	(M	)	--	--
		Mean =	All Subjects	11.0	8.9	--	--	--	--
Med, 60 kt, SS4	529	43	N	9.5	9.0	(S	)	--	--
		59	N	7.7	9.3	(S	)	--	--
	530	40	D	8.5	7.4	(S	)	--	--
		51	D	9.8	12.5	(S	)	--	--
	532	56	N	11.2	14.2	(S	)	--	--
		60	N	12.6	11.0	(S	)	--	--
	533	61	D	13.6	11.8	(M	)	--	--
		57	D	(M	)	(M	)	--	--

CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	TEST 1 (1ST DAY)		TEST 2 (2ND DAY)		MEAN TESTS 1 & 2	
				DECODE	ENCODE	DECODE	ENCODE	DECODE	ENCODE
		Mean = All Subjects		10.4	10.7				
Full, 60 kt, SS4	446	52	N	10.7(I)	9.5(I)	(M-E)		--	--
		47	D	(F)		(E)		--	--
	451	49	N	9.8	8.0	(M)		--	--
		47	D	(M)		(M)		--	--
	550	40	N	11.4	10.4	(M)		--	--
		60	D	(M)		(M)		--	--
	540	43	N	15.3	14.9	(S)		--	--
		60	N	11.5	10.5	(S)		--	--
	541	40	D	13.2	9.8	(S)		--	--
		51	D	10.2	12.2	(S)		--	--
		Mean = All Subjects		11.7	10.8	--	--	--	--

CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	TEST 1 (1ST DAY) DECODE	TEST 1 (1ST DAY) ENCODE	TEST 2 (2ND DAY) DECODE	TEST 2 (2ND DAY) ENCODE	MEAN TESTS 1 & 2 DECODE	MEAN TESTS 1 & 2 ENCODE
Med, 40 kt, SS5	535	43	N	12.2	13.1	(S)		--	--
		59	N	(M)		(M)		--	--
	536	40	D	11.8	10.2	(S)		--	--
		51	D	11.5	12.0	(S)		--	--
	538	56	D	(M)		(M)		--	--
		60	D	13.1	8.9	(S)		--	--
Mean = All Subjects				12.2	11.1	--	--	--	--
Full, 40 kt, SS5	494	43	N	16.0	(0)	17.4	8.5	16.7	--
		50	D	(M)		(M)		--	--
	496	39	N	(M)		M-E)		--	--
		51	D	9.5	10.1	(E)		--	--
	547	43	D	13.5	12.3	17.6	13.9	12.9	13.1
		51	N	10.3	12.1	11.0	10.3	10.7	11.2
	543	43	N	13.6	14.6	(S)		--	--
		60	N	13.4	11.5	(S)		--	--

CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	TEST 1 (1ST DAY)		TEST 2 (2ND DAY)		MEAN TESTS 1 & 2	
				DECODE	ENCODE	DECODE	ENCODE	DECODE	ENCODE
Full, 40 kt, SS5 (Cont)	545	40	D	(M	)	(M	)	--	--
		51	D	11.9	12.3	(S	)	--	--
		Mean =	N Sleepers	13.3	12.7	14.2	9.4	13.7	--
			D Sleepers	11.6	11.6	--	--	--	--
			All Subjects	12.6	12.2	13.1	10.9	13.4	12.2

Note: Characters within the table indicate the following:

O = Observer error, no time recorded.
E = Equipment failure.
S = Scheduled termination.
I = Evidence of subject ill (motion sick) during test.
M = Subject aborts due to motion sickness.

APPENDIX G

SUMMARY OF NAVIGATION RESULTS FROM THE STATIC CONDITION:
AVERAGE DISTANCE ERROR OF PLOTTED CONTACTS (IN NAUTICAL MILES)
BY SUBJECTS, RUNS, AND TESTS (DAYS) WITHIN RUNS

SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	STATIC RUN SEQUENCE	TEST 1 (FIRST DAY)	TEST 2 (SECOND DAY)	MEAN TESTS 1 AND 2
50	N	1	(X)	1.5	--
		2	.8	1.0	--
		3	.8	.5	--
		Mean =	.8	1.0	--
43	D	1	1.5	1.0	1.3
		2	1.3	1.0	1.2
		3	1.0	1.3	1.2
	N	4	1.0	--	--
		5	1.5	--	--
		6	1.3	--	--
		Mean =	1.3	1.1	1.2
48	N	1	1.5	.5	1.0
		2	1.5	--	--
		Mean =	1.5	--	--

SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	STATIC RUN SEQUENCE	TEST 1 (FIRST DAY)	TEST 2 (SECOND DAY)	MEAN TESTS 1 AND 2
39	D	1	3.8	1.0	--
		2	1.3	--	--
		Mean =	2.6	--	--
44	N	1	1.0	1.8	--
		2	1.5	--	--
		Mean =	1.3	--	--
49	D	1	.8	.5	--
		2	1.0	--	--
		3	.5	--	--
		Mean =	.8	--	--
52	N	1	.8	.5	--
		2	.8	--	--
		Mean =	.8	--	--

SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	STATIC RUN SEQUENCE	TEST 1 (FIRST DAY)	TEST 2 (SECOND DAY)	MEAN TESTS 1 AND 2
38	D	1	.8	--	--
51	D	1	(	X)	9.0
	N	2	1.3	--	--
		3	0.5	--	--
		4	2.3	--	--
			Mean = 1.4	--	--
40	N	1	1.3	.8	1.1
		2	.8	--	--
		3	1.3	--	--
		4	1.5	--	--
			Mean = 1.2	--	--
60	D	1	1.0	1.0	1.0
		2	.5	--	--
		3	1.0	--	--
		4	1.0	--	--
			Mean = .9	--	--

SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	STATIC RUN SEQUENCE	TEST 1 (FIRST DAY)	TEST 2 (SECOND DAY)	MEAN TESTS 1 AND 2
61	N	1	(	X)	9.0
		2	.8	--	--
		3	2.3	--	--
			Mean = 1.6	--	--
56	D	1	.8	.8	.8
		2	.8	--	--
		3	1.3	--	--
			Mean = 1.0	--	--
47	D	1	1.0	1.5	1.3
		2	1.0	--	--
			Mean = 1.0	--	--
59	N	1	1.5	--	--
		2	2.0	--	--
			Mean = 1.8	--	--

X = Task performed improperly or not completed.

APPENDIX H

SUMMARY OF NAVIGATION RESULTS FROM THE MOTION CONDITIONS: AVERAGE DISTANCE ERROR OF PLOTTED CONTACTS (IN NAUTICAL MILES) BY SUBJECTS, RUNS, AND TESTS (DAYS) WITHIN RUNS

CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	TEST 1 (FIRST DAY)	TEST 2 (SECOND DAY)	MEAN TESTS 1 AND 2
Low, 80 kt, SS3	483	50	N	1.8	1.5	1.6
		43	D	1.3	1.5	1.4
	485	48	N	(X)	1.5	--
		39	D	2.3	3.3	2.8
		Mean =	N Sleepers	--	1.5	--
			D Sleepers	1.8	2.4	2.1
			All Subjects	1.8	2.0	1.9
Med, 80 kt, SS3	424	49	N	.5	(E)	--
		44	D	(E)		--
	439	52	N	1.5	(S)	--
		47	D	(X-I)	(M-S)	--
	440	49	N	.5	(S)	--
		44	D	(M)	(S)	--
		38	D	(X)	(S)	--

CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	TEST 1 (FIRST DAY)	TEST 2 (SECOND DAY)	MEAN TESTS 1 AND 2
Med, 80 kt, SS3 (Cont'd)	455	46	N	.5	(M)	--
		38	D	(M	)	--
	457	49	N	1.0	(S)	--
		35	D	7.0	(S)	--
			Mean = N Sleepers	.9	--	--
			D Sleepers	--	--	--
			All Subjects	1.8	--	--
Full, 80 kt, SS3	487	43	N	.5	(E)	--
		50	D	1.8	(E)	--
	489	39	N	1.8	2.5	2.2
		48	D	(M	)	--
		51	D	(T	)	--
	525	40	N	2.5	2.0	2.3
		60	D	1.8	2.0	1.9
	527	61	N	1.8	1.8	1.8
		56	D	4.2	3.5	3.9
			Mean = N Sleepers	1.7	2.1	2.1
			D Sleepers	1.9	1.8	2.0
			All Subjects	1.8	2.0	2.1

CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	TEST 1 (FIRST DAY)	TEST 2 (SECOND DAY)	MEAN TESTS 1 AND 2
Low, 60 kt, SS4	453	46	N	.5	(S)	--
		38	D	(X)	(S)	--
	454	49	N	.5	(S)	--
		47	D	(M)	(S)	--
			Mean = N Sleepers	.5	--	--
			All Subjects	.5	--	--
Med, 60 kt, SS4	529	43	N	2.2	(S)	--
		59	N	2.4	(S)	--
	530	40	D	1.8	(S)	--
		51	D	1.3	(S)	--
	532	56	N	.8	(S)	--
		60	N	1.2	(S)	--
	533	61	D	.5	(S)	--
		57	D	(M)	(S)	--
			Mean = All Subjects	1.5	--	--

CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	TEST 1 (FIRST DAY)	TEST 2 (SECOND DAY)	MEAN TESTS 1 AND 2
Full, 60 kt, SS4	446	52	N	2.5(I)	(M-E)	--
		47	D	(E	)	--
	451	49	N	1.0	(M)	--
		47	D	(M	)	--
	550	40	N	1.8	(M)	--
		60	D	(M	)	--
	540	43	N	1.8	(S)	--
		60	N	1.3	(S)	--
	541	40	D	.8	(S)	--
		51	D	1.0	(S)	--
		Mean = All Subjects		1.5	--	--
Med, 40 kt, SS5	535	43	N	1.8	(S)	--
		59	N	6.3(I)	(M-S)	--
	536	40	D	3.2	(S)	--
		51	D	.8	(S)	--

CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	TEST 1 (FIRST DAY)	TEST 2 (SECOND DAY)	MEAN TESTS 1 AND 2
Med, 40 kt, SS5 (Cont'd)	538	56	D	1.8	(M-S)	--
		60	D	1.0	(S)	--
Mean = All Subjects				2.4	--	--
Full, 40 kt, SS5	494	43	N	2.3	1.8	2.1
		50	D	(	M)	--
	496	39	N	2.8	(M)	--
		51	D	2.8	(E)	--
	547	51	N	1.5	.8	1.2
		43	D	.8	1.0	.9
	543	43	N	.5	(S)	--
		60	N	1.0	(S)	--
	545	40	D	(	M)	--
		51	D	(T)	(S)	--

CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	TEST 1 (FIRST DAY)	TEST 2 (SECOND DAY)	MEAN TESTS 1 AND 2
			Mean = N Sleepers	1.6	--	--
			Mean = D Sleepers	1.8	--	--
			Mean = All Subjects	1.7	1.2	1.4

Note: Characters within the table indicate the following:

X = Task performed improperly or not completed.
E = Equipment failure.
S = Scheduled termination.
I = Evidence of subject ill (motion sick) during test.
M = Subject aborts due to motion sickness.
T = Test not administered due to failure of test apparatus.

APPENDIX I

SUMMARY OF VISUAL ACUITY RESULTS FROM THE STATIC CONDITION: VISUAL ANGLE (IN MINUTES OF ARC) OF SMALLEST PRINT CORRECTLY READ BY SUBJECTS AT BEGINNING (B) AND END (E) OF WORK CYCLE OVER RUNS AND TESTS (DAYS) WITHIN RUNS

SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	STATIC RUN SEQUENCE	TEST 1 (FIRST DAY)		TEST 2 (SECOND DAY)		MEAN TESTS 1 AND 2	
			B	E	B	E	B	E
50	N	1	5.25	4.50	4.88	4.13	5.07	4.32
		2	4.13	4.13	4.13	4.13	4.13	4.13
		3	4.50	4.50	4.13	4.13	4.22	4.22
		Mean =	4.63	4.38	4.38	4.13	4.47	4.22
43	D	1	3.56	3.75	3.56	3.56	3.56	3.66
		2	3.56	3.56	3.56	3.56	3.56	3.56
		3	3.56	3.56	3.48	3.56	3.52	3.56
	N	4	3.56	3.56	-	-	-	-
		5	3.56	3.38	-	-	-	-
		6	3.38	3.56	-	-	-	-
		Mean =	3.53	3.56	3.53	3.56	3.55	3.59
48	N	1	(T)	4.50	3.56	3.75	-	4.13
		2	3.56	3.38	-	-	-	-
		Mean =	-	3.94	-	-	-	-

SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	STATIC RUN SEQUENCE	TEST 1 (FIRST DAY) B	TEST 1 (FIRST DAY) E	TEST 2 (SECOND DAY) B	TEST 2 (SECOND DAY) E	MEAN TESTS 1 AND 2 B	MEAN TESTS 1 AND 2 E
39	D	1	3.75	4.13	-	-	-	-
		2	3.75	3.75	3.75	4.13	3.75	3.94
		Mean =	3.75	3.94	-	-	-	-
44	N	1	4.50	4.50	4.13	4.13	4.32	4.32
		2	(T)	3.75	-	-	-	-
		Mean =	-	4.13	-	-	-	-
49	D	1	4.88	4.50	4.13	3.75	4.51	4.13
		2	4.50	4.13	-	-	-	-
		Mean =	4.69	4.32	-	-	-	-
52	N	1	3.56	4.50	4.13	4.50	3.85	4.50
		2	4.50	3.56	-	-	-	-
		Mean =	4.03	4.03	-	-	-	-
57	D	1	3.75	3.75	-	-	-	-
		2	3.75	3.56	-	-	-	-
		Mean =	3.66	3.66	-	-	-	-

SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	STATIC RUN SEQUENCE	TEST 1 (FIRST DAY)		TEST 2 (SECOND DAY)		MEAN TESTS 1 AND 2	
			B	E	B	E	B	E
38	D	1	5.45	5.63	-	-	-	-
51	D	1	4.13	4.13	3.75	3.56	3.94	3.85
	N	2	3.56	4.13	-	-	-	-
		3	3.38	3.18	-	-	-	-
		4	4.13	3.75	-	-	-	-
		Mean =	3.80	3.80	-	-	-	-
40	N	1	(T)	4.88	3.56	3.75	-	4.32
		2	3.55	3.56	-	-	-	-
		3	3.56	3.75	-	-	-	-
		4	3.56	3.56	-	-	-	-
		Mean =	3.56	3.94	-	-	-	-
60	D	1	3.75	-	3.38	3.00	3.5[illegible]	-
		2	3.56	3.38	-	-	-	-
		3	3.38	3.38	-	-	-	-
		4	3.38	3.18	-	-	-	-
		Mean =	3.52	3.31	-	-	-	-

SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	STATIC RUN SEQUENCE	TEST 1 (FIRST DAY) B	TEST 1 (FIRST DAY) E	TEST 2 (SECOND DAY) B	TEST 2 (SECOND DAY) E	MEAN TESTS 1 AND 2 B	MEAN TESTS 1 AND 2 E
61	N	1	3.18	3.18	3.38	3.38	3.28	3.28
		2	3.00	3.00	-	-	-	-
		3	3.38	3.38	-	-	-	-
		Mean =	3.19	3.19	-	-	-	-
56	D	1	3.56	3.56	3.56	3.56	3.56	3.56
		2	3.56	3.56	-	-	-	-
		3	4.13	3.56	-	-	-	-
		4	3.56	(T)	-	-	-	-
		Mean =	3.70	3.56	-	-	-	-
47	D	1	7.51	5.25	4.50	(T)	6.01	-
		2	5.25	4.50	-	-	-	-
		Mean =	6.38	4.88	-	-	-	-
59	N	1	3.56	3.56	-	-	-	-
		2	3.56	4.13	-	-	-	-
		Mean =	3.56	3.85	-	-	-	-

T = Test not administered due to failure of test apparatus.

APPENDIX J

SUMMARY OF VISUAL ACUITY RESULTS FROM THE MOTION CONDITION:
VISUAL ANGLE (IN MINUTES OF ARC) OF SMALLEST PRINT CORRECTLY READ BY SUBJECTS
AT BEGINNING (B) AND END (E) OF WORK CYCLE
OVER RUNS AND TESTS (DAYS) WITHIN RUNS

CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	TEST 1 (FIRST DAY)		TEST 2 (SECOND DAY)		MEAN TESTS 1 AND 2	
				B	E	B	E	B	E
Low, 80 kt, SS3	483	50	N	4.50	4.50	4.88	4.13	4.69	4.32
		43	D	4.13	4.50	3.56	3.56	3.85	4.03
	485	48	N	4.13	4.50	3.75	4.88	3.94	4.69
		39	D	3.75	4.03	3.75	4.13	3.75	4.13
		Mean =	N Sleepers	4.32	4.50	4.32	4.51	4.32	4.51
			D Sleepers	3.94	4.32	3.66	3.85	3.80	4.08
			All Subjects	4.13	4.41	3.99	4.18	4.06	4.30
Med, 80 kt, SS3	424	49	N	4.50	4.50	(E	)	-	-
		44	D	(E	)	(E	)	-	-
	439	52	N	4.50	4.50	(S	)	-	-
		47	D	(T)	5.63(I)	(M-S	)	-	-
	440	49	N	4.50	3.56	(S	)	-	-
		44	D	(M	)	(M-S	)	-	-
		38	D	5.63	6.55	(S	)	-	-

CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	TEST 1 (FIRST DAY)		TEST 2 (SECOND DAY)		MEAN TESTS 1 AND 2	
				B	E	B	E	B	E
Med, 80 kt, SS3 (Cont'd)	455	46	N	4.50	4.88	(M)		-	-
		38	D	(M)		(M)		-	-
	457	49	N	4.50	4.13	(S)		-	-
		35	D	3.56	3.56	(S)		-	-
		Mean =	N Sleepers	4.50	4.31	-	-	-	-
			D Sleepers	4.60	5.25	-	-	-	-
			All Subjects	4.53	4.66	-	-	-	-
Full, 80 kt, SS3	487	43	N	3.75	4.13	(E)		-	-
		50	D	4.50	4.88	(E)		-	-
	489	39	N	5.25	4.50	(T)	4.50	-	4.50
		48	D	(M)		(M)		-	-
		51	D	3.75	5.25	4.50	4.13	4.13	4.69
	525	40	N	4.50	4.88	4.50	4.50	4.50	4.69
		60	D	3.38	3.56	3.56	4.13	3.47	3.85
	527	61	N	3.56	3.75	3.56	3.56	3.56	3.66
		56	D	3.75	3.75	4.13	4.13	3.94	3.94

CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	TEST 1 (FIRST DAY)		TEST 2 (SECOND DAY)		MEAN TESTS 1 AND 2	
				B	E	B	E	B	E
		Mean =	N Sleepers	4.27	4.32	4.03	4.19	4.03	4.28
			D Sleepers	3.85	4.36	4.06	4.13	3.85	4.16
			All Subjects	4.06	4.34	4.05	4.16	3.92	4.22
Low, 60 kt, SS4	453	46	N	4.88	4.50	(S)		-	-
		38	D	5.63	(T)	(S)		-	-
	454	49	N	4.50	4.50	(S)		-	-
		47	D	(M)		(S)		-	-
		Mean =	N Sleepers	4.69	4.50	-	-	-	-
			All Subjects	5.00	4.50	-	-	-	-
Med, 60 kt, SS4	529	43	N	3.56	3.56	(S)		-	-
		59	N	3.56	(T)	(S)		-	-
	530	40	D	4.50	4.50	(S)		-	-
		51	D	4.88	3.56	(S)		-	-
	532	56	N	4.50	3.75	(S)		-	-
		60	N	4.13	3.56	(S)		-	-
	533	61	D	3.56	(M)	(S)		-	-
		57	D	4.88	(M)	(S)		-	-
		Mean =	All Subjects	4.20	3.79	-	-	-	-

CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	TEST 1 (FIRST DAY)		TEST 2 (SECOND DAY)		MEAN TESTS 1 AND 2	
				B	E	B	E	B	E
Full, 60 kt, SS4	446	52	N	4.13	(M)	(E)		-	-
		47	D	(E)		(E)		-	-
	451	49	N	4.50	4.50(I)	(M)		-	-
		47	D	(M)		(M)		-	-
	550	40	N	3.56	4.13	(M)		-	-
		60	D	(M)		(M)		-	-
	540	43	N	3.56	3.38	(S)		-	-
		60	N	3.38	3.56	(S)		-	-
	541	40	D	4.13	4.50	(S)		-	-
		51	D	3.75	3.56	(S)		-	-
Mean = All Subjects				3.86	3.94	-	-	-	-
Med, 40 kt, SS5	535	43	N	4.13	4.50	(S)		-	-
		59	N	4.13	(M)	(S)		-	-
	536	40	D	3.75	4.13	(S)		-	-
		51	D	3.56	4.13	(S)		-	-
	538	56	D	3.56	(M)	(S)		-	-
		60	D	3.38	3.56	(S)		-	-

CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	TEST 1 (FIRST DAY)		TEST 2 (SECOND DAY)		MEAN TESTS 1 AND 2	
				B	E	B	E	B	E
		Mean =	All Subjects	3.75	4.08	-	-	-	-
Full, 40 kt, SS5	494	43	N	(T)		(T)		-	-
		50	D	(M)		(M)		-	-
	496	39	N	(I)4.13	(M)	(M)		-	-
		51	D	4.13	3.75	(E)		-	-
	547	51	N	3.75	3.75	3.56	4.13	-	-
		43	D	4.13	3.56	4.13	3.38	-	-
	543	43	N	3.56	4.50	(S)		-	-
		60	N	3.56	3.56	(S)		-	-
	545	40	D	3.75	(M)	(M)		-	-
		51	D	4.13	3.75	(S)		-	-
		Mean =	N Sleepers	3.75	3.94	-	-	-	-
			D Sleepers	4.04	3.69	-	-	-	-
			All Subjects	3.89	3.81	3.85	3.76	-	-

Note: Characters within the table indicate the following:

E = Equipment failure.
S = Scheduled termination.
T = Test not administered due to failure of test apparatus.
M = Subject aborts due to motion sickness.
I = Evidence of subject ill (motion sick) during test.

APPENDIX K

SUMMARY OF CONDITIONS: SUBJECTS AND MEASUREMENTS FOR SLEEPINESS RATINGS

CONDITION	RUN NO.	SUBJECT	SLEEP SCHEDULE	NUMBER OF MEASUREMENTS
Low, 80 kt, SS3	483	43	N	9
		50	D	8
	485	39	N	10
		48	D	7
Med, 80 kt, SS3	424	49	N	2
	439	47	D	5
	440	49	N	5
		38	D	5
	457	49	N	5
Full, 80 kt, SS3	487	43	N	5
		50	D	3
	489	39	N	9
		51	D	4

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CONDITION	RUN NO.	SUBJECT	SLEEP SCHEDULE	NUMBER OF MEASUREMENTS
Full, 80 kt, SS3 (cont'd)	525	40	N	10
		60	D	10
	527	61	N	10
		56	D	10
Low, 60 kt, SS4	453	38	D	5
	454	49	N	5
		47	D	2
Full, 60 kt, SS4	446	47	D	2
	451	49	N	4
Full, 40 kt, SS5	494	43	N	9
	496	39	N	1
		51	D	4

APPENDIX L

CATECHOLAMINE MEASUREMENTS IN PHASE 2
(IN NANOGRAMS/MINUTE)

STATIC CONDITION: LONG MISSIONS (RUNS > 24 HOURS)

SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	STATIC RUN SEQUENCE	FIRST DAY				SECOND DAY			
			WAKE		SLEEP		WAKE		SLEEP	
			$\dot{A}$	$N\dot{A}$	$\dot{A}$	$N\dot{A}$	$\dot{A}$	$N\dot{A}$	$\dot{A}$	$N\dot{A}$
49	N	1	21.3	34.4	8.8	12.5	10.4	18.0	5.6	9.3
		2	9.8	22.3	5.0	15.2	--	--	--	--
		3	8.9	24.6	3.1	9.3	--	--	--	--
		Mean =	15.5	28.3	5.6	12.3	10.4	18.0	5.6	9.3
44	D	1	7.6	19.6	9.1	16.8	7.2	13.4	5.4	10.3
		2	3.1	18.5	7.0	11.8	--	--	--	--
		Mean =	5.4	19.1	8.1	14.3	7.2	13.4	5.4	10.3
52	N	1	7.9	18.3	5.0	10.1	8.9	16.0	4.2	8.5
		2	8.3	36.3	4.1	15.0	--	--	--	--
		Mean =	8.1	27.3	4.6	12.6	8.9	16.0	4.2	8.5
47	D	1	10.3	26.1	10.1	19.8	8.2	15.8	4.7	9.6
		2	7.2	29.7	9.2	17.3	--	--	--	--
		Mean =	8.8	27.9	9.7	18.5	8.2	15.8	4.7	9.6

SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	STATIC RUN SEQUENCE	FIRST DAY				SECOND DAY			
			WAKE		SLEEP		WAKE		SLEEP	
			$\dot{A}$	$N\dot{A}$	$\dot{A}$	$N\dot{A}$	$\dot{A}$	$N\dot{A}$	$\dot{A}$	$N\dot{A}$
38	D	1	10.6	24.1	13.7	27.7	--	--	--	--
43	N	1	11.2	23.4	4.5	13.8	--	--	--	--
		2	9.6	28.3	5.3	13.5	10.9	21.3	5.0	17.7
		3	5.8	17.4	3.9	9.7	7.8	20.0	3.8	9.3
		Mean =	8.9	23.0	4.6	12.3	9.4	20.7	4.4	13.5
50	D	1	6.7	29.7	4.4	18.1	5.7	7.3	5.6	23.3
		2	--	--	3.7	13.9	2.8	13.5	5.9	22.4
		3	2.8	14.6	6.0	22.4	2.4	11.7	--	--
		Mean =	4.8	22.2	4.7	18.1	3.6	10.8	5.8	22.9
39	N	1	8.0	30.8	6.8	16.0	5.2	18.3	6.9	18.9
		2	--	--	5.7	22.0	--	--	--	--
		3	8.3	15.8	5.9	22.9	8.1	25.8	15.5	43.2
		Mean =	8.2	23.3	6.1	20.3	6.7	22.1	11.2	31.1

SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	STATIC RUN SEQUENCE	FIRST DAY				SECOND DAY			
			WAKE		SLEEP		WAKE		SLEEP	
			$\dot{A}$	$N\dot{A}$	$\dot{A}$	$N\dot{A}$	$\dot{A}$	$N\dot{A}$	$\dot{A}$	$N\dot{A}$
48	D	1	4.9	18.0	10.0	23.5	7.0	19.5	8.6	22.5
		2	--	--	6.4	16.4	--	--	--	--
		Mean =	4.9	18.0	8.2	19.9	7.0	19.5	8.6	22.5
51	N	1	9.4	40.4	6.6	25.8	11.1	41.2	5.8	17.8
40	N	1	7.5	22.0	3.1	11.8	11.9	32.8	5.0	10.3
60	D	1	4.7	12.2	8.2	22.9	8.5	20.4	5.8	14.4
61	N	1	7.7	19.5	4.0	12.7	6.7	18.3	4.5	11.4
56	D	1	5.0	22.2	4.5	12.6	10.1	47.7	3.0	7.1

STATIC CONDITION: SHORT MISSIONS (RUNS = 6 HOURS)

SUBJECT NUMBER	STATIC RUN SEQUENCE	$\dot{A}$	$\dot{N}A$
43	1	6.8	16.9
	2	--	--
	3	5.1	19.5
	Mean =	6.0	18.2
60	1	6.4	12.9
	2	7.0	17.7
	3	10.3	36.7
	Mean =	7.9	22.4
40	1	16.0	34.4
	2	6.7	20.3
	3	10.2	22.3
	Mean =	11.0	25.7
51	1	20.7	43.7
	2	8.2	21.0
	3	10.2	22.3
	Mean =	13.0	29.0

SUBJECT NUMBER	STATIC RUN SEQUENCE	$\dot{A}$	$\dot{N}A$
56	1	7.2	20.3
	2	4.1	15.8
	3	6.9	23.4
	Mean =	6.1	19.8
59	1	8.7	24.3
	2	6.4	16.2
	Mean =	7.6	20.3
61	1	16.4	44.3
	2	6.0	17.4
	Mean =	11.2	30.9
57	1	8.4	15.8
	2	9.2	20.4
	Mean =	8.8	18.1

MOTION CONDITIONS

CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	FIRST DAY WAKE $\dot{A}$	FIRST DAY WAKE $\dot{N}A$	FIRST DAY SLEEP $\dot{A}$	FIRST DAY SLEEP $\dot{N}A$	SECOND DAY WAKE $\dot{A}$	SECOND DAY WAKE $\dot{N}A$	SECOND DAY SLEEP $\dot{A}$	SECOND DAY SLEEP $\dot{N}A$
Low, 80 kt, SS3	483	50	D	9.9	38.6	4.2	15.0	3.9	20.6	5.0	11.6
		43	N	5.6	15.5	8.0	16.5	10.9	28.8	3.8	9.4
	485	48	N	5.5	19.7	8.0	21.7	8.1	22.9	8.7	21.7
		39	D	10.9	22.5	8.3	15.5	10.9	22.5	3.5	13.7
			Mean =	8.0	24.1	7.1	17.2	8.5	23.7	5.3	14.1
Med, 80 kt, SS3	439	52	N	10.3	21.2	3.8	10.9	--	--	--	--
		47	D	--	--	12.5	13.8	--	--	--	--
	440	49	N	13.7	34.4	4.4	12.0	--	--	--	--
		44	D	--	--	6.6	17.8	--	--	--	--
		38	N	16.4	45.9	--	--	--	--	--	--
	457	49	N	--	--	4.3	11.3	--	--	--	--
			Mean =	13.5	33.8	6.3	13.2	--	--	--	--

CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	FIRST DAY				SECOND DAY			
				WAKE		SLEEP		WAKE		SLEEP	
				$\dot{A}$	$N\dot{A}$	$\dot{A}$	$N\dot{A}$	$\dot{A}$	$N\dot{A}$	$\dot{A}$	$N\dot{A}$
Full, 80 kt, SS3	487	43	N	9.6	28.7	3.7	12.3	--	--	--	--
		50	D	--	--	6.5	21.1	--	--	--	--
	489	39	N	4.8	18.3	6.9	24.7	5.6	25.0	3.5	13.8
		48	D	--	--	12.0	27.8	--	--	--	--
		51	D	10.4	29.2	--	--	8.2	21.1	12.5	42.9
	525	40	N	14.3	22.1	3.3	8.3	16.4	33.1	3.4	10.1
		60	D	11.8	22.8	10.5	18.7	13.3	23.5	6.3	12.2
	527	61	N	8.6	19.0	3.9	10.1	3.0	7.1	--	--
		56	D	3.7	12.1	3.1	8.8	2.5	7.5	4.7	13.5
			Mean =	9.0	21.7	6.2	16.5	8.2	19.6	6.1	18.5
Low, 60 kt, SS4	453	38	D	19.5	49.2	9.9	20.2	--	--	--	--
	454	49	N	15.7	38.6	3.6	12.4	--	--	--	--
		47	D	--	--	8.4	23.4	--	--	--	--
			Mean =	17.6	43.9	7.3	18.7	--	--	--	--

CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	FIRST DAY WAKE $\dot{A}$	FIRST DAY WAKE $\dot{NA}$	FIRST DAY SLEEP $\dot{A}$	FIRST DAY SLEEP $\dot{NA}$	SECOND DAY WAKE $\dot{A}$	SECOND DAY WAKE $\dot{NA}$	SECOND DAY SLEEP $\dot{A}$	SECOND DAY SLEEP $\dot{NA}$
Med, 60 kt, SS4	529	43	Short Missions	18.6	29.4						
		59		7.4	24.3						
	530	40		7.8	17.8						
		51		12.5	28.3						
	532	56		7.3	20.4						
		60		20.1	39.3						
	533	61		8.6	16.0						
		57		20.9	28.8						
			Mean =	12.9	25.6						
Full, 60 kt, SS4	446	52	N	11.1	24.2	--	--	--	--	--	--
		47	D	9.7	33.3	9.3	21.6	--	--	--	--
	550	40	N	28.0	27.8	--	--	--	--	--	--
		60	D	--	--	26.6	30.4	--	--	--	--
	540	43	Short Missions	6.4	20.4						
		60		25.9	53.9						
	541	40		21.7	19.5						
		51		14.2	38.4						
			Mean =	16.7	31.1	17.9	26.0				

CONDITION	RUN NO.	SUBJECT NUMBER	DAY (D) OR NIGHT (N) SLEEPER	FIRST DAY				SECOND DAY			
				WAKE		SLEEP		WAKE		SLEEP	
				$\dot{A}$	$N\dot{A}$	$\dot{A}$	$N\dot{A}$	$\dot{A}$	$N\dot{A}$	$\dot{A}$	$N\dot{A}$
Med, 40 kt, SS5	535	43	Short Missions	22.2	7.1						
		59		30.9	16.5						
	536	40		23.4	9.8						
		51		36.6	9.9						
	538	56		18.8	10.7						
		60		33.7	18.4						
			Mean =	27.6	12.1						
Full, 40 kt, SS5	494	43	N	7 3	20.3	4.2	12.9	7.4	24.0	4.2	11.2
	496	39	N	6.8	24.8	4.2	15.7	--	--	--	--
		51	D	8.7	28.7	5.2	18.2	--	--	--	--
	547	51	N	17.9	40.1	[illegible]	9.9	22.1	28.9	6.0	10.6
		43	D	9.2	24.3	--	--	7.9	23.1	4.2	16.0
	543	43	Short Missions	13.1	37.5						
		60		17.3	48.2						
	545	40		17.4	18.8						
		51		16.5	43.0						
			Mean =	12.7	31.7	4.1	14.2	12.5	25.3	4.8	12.6